The University of Chicago

MINERAL RESOURCES OF CHINA

A DISSERTATION SUBMITTED TO THE FACULTY OF THE DIVISION OF THE PHYSICAL SCIENCES IN CANDIDACY FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

DEPARTMENT OF GEOLOGY

1945

By

VEI CHOW JUAN

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VEI CHOW JUAN.

ABSTRACT.

This study is an attempt to present, in concise form the available information on the mining industry and mineral resources of China, and, to determine her place in the world economic structure. It is based on a detailed report prepared by the writer while in the staff of the U. S. Geological Survey. The detailed report was undertaken by the Geological Survey at the request of the Office of the Chief of Engineers, U. S. Army, which financed most of the work.

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INTRODUCTION.

CHINA, the great power of Asia, is destined to become economically independent and to approach self-sufficiency in the post-war era. A general

analysis of China's industrial potentialities supports the belief that, within twenty-five years, Chinese industry, based on mineral resources, will surpass that achieved by pre-war Japan, and will eventually absorb all the markets in the Far East that were formerly in Japanese possession. Information accumulated by the National Geological Survey of China, permits a dependably clear general outline of China's mineral resources. It should, however, be emphasized that, although the important mineral resources in the Chinese territory are reasonably well known, future exploration may change the picture with respect to certain items, especially those in the more remote regions.

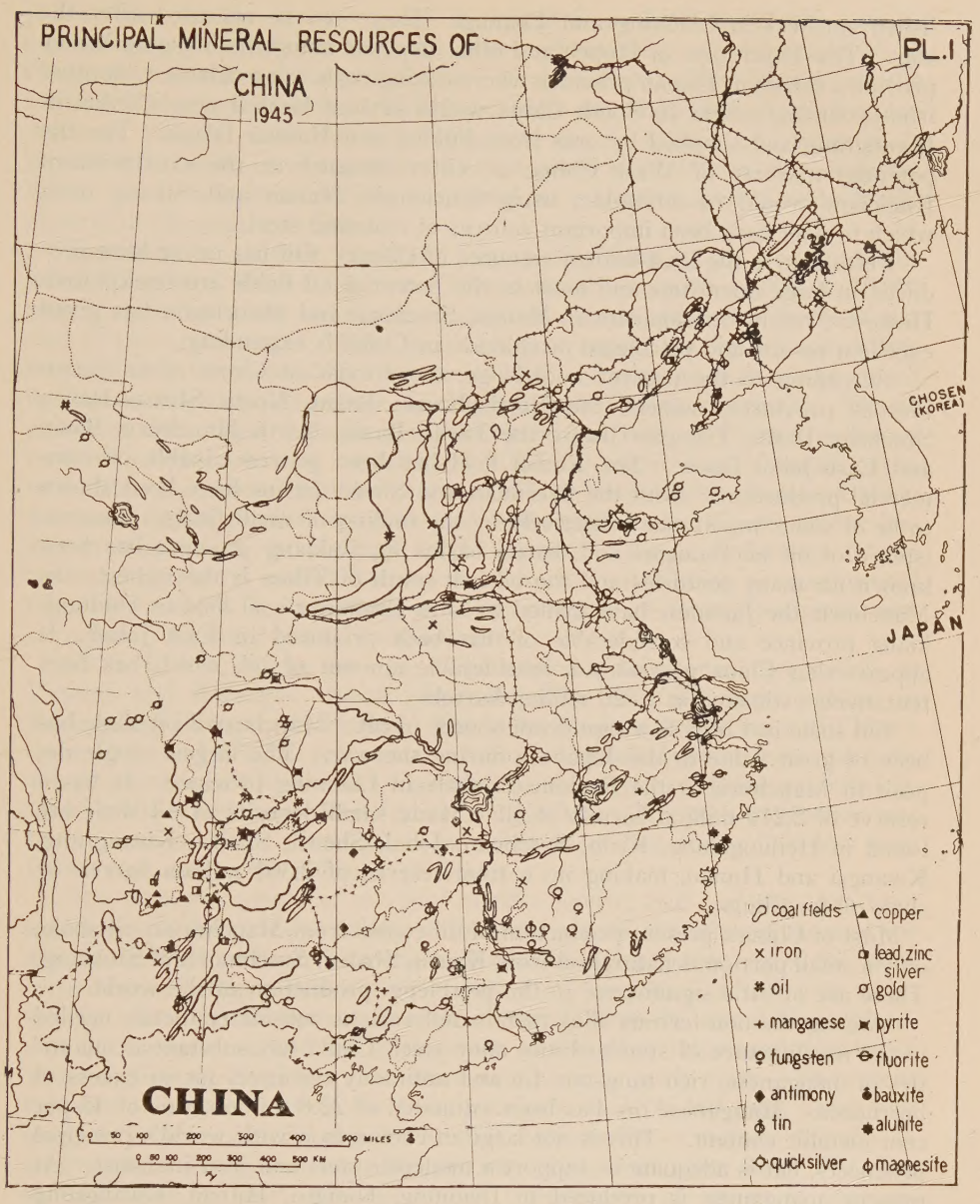
China's coal resources are her greatest potential source of power. The latest and most conservative estimate of the coal reserves is 240,847 million tons. This figure places China fourth in the world's coal reserves, being exceeded only by those for the United States, Canada and Russia. It is less than one-tenth of the reserves of the United States and about one-third of those of Canada and Russia.

Coal deposits in China are widely distributed (Fig. 1), being found in nearly every province, although 83 per cent of China's coal is located in the provinces of Shansi and Shensi in North China. This is the largest concentration available for industrialization. Honan ranks third with 3.8 per cent. Szechuan in South China has 2.5 per cent, and 10 per cent of coal is scattered among the remaining 24 provinces. Coals in China are of high rank for the most part. Bituminous coal amounts to 78 per cent of the total reserves. The quantity suitable for making coke is considerable, and is mainly close to the source of iron ore.

The annual pre-war coal production in China was about 32 million tons, half of which was used for domestic heating. The major productive centers, Manchuria and North China, produced more than 85 per cent of the total. The westward movement of industrialization since 1937 is shown by the coal industry. In 1939, this western region produced more than 3 million tons of coal. Although the war-time development of coal industry in the southwest will be of great value to China, the base of heavy industry still lies near the northeast seaboard where modern transport makes the coal more accessible for the creation of a modern state in China.

Estimates of iron reserves in China vary greatly. It is reported that the Japanese exploration in Manchuria has suggested a total for China of 1,218,000 million tons. The reliability of this figure is still questioned. But with great certainty, we know now that the total reserves of iron ore for China are no less than 1,484 million tons and may possibly reach 1,821 million tons. The Manchurian ores amount to 60 per cent of the total, but they are mostly of low grade, having an average of about 30 per cent iron. Good grade ores are found in China proper. The Chahar deposits are estimated at 92 million tons of high-grade ore. In Yangtze Valley and southwestern China there are many high-grade deposits though they are individually small and widely scattered.

Compared with China's coal resources, the iron reserve is less promising for building a steel industry comparable to that of the United States. However, the domination and control of heavy industry by the state is justified on



the ground of attaining self-sufficiency and assuring the greatest possible development of the nation, and lack of high-grade iron ore can be remedied by importation of ore from the Philippines and possibly from India.

It is, therefore, economically justifiable to plan a steel industry, based on Chinese ores, in the post-war period. There are five potential iron-producing centers in China. Manchuria and Chahar ores have been used for well estab-

lished smelters in Liaoning and Peiping. These can be operated after the war. The Tayeh ores of Hupeh and other deposits along the Yangtze Valley provide a center in Hunan province where coking coals are available. Another iron-producing center in South China would be best located near Canton in Kwangtung and supplied by ores from Fukien and Hainan Island. For the potential markets of West China, a center situated in the northwestern Kueichow would be advisable, using Kueichow, Hunan and Sikang ores, which to date have been important sources of iron and steel.

Petroleum is the least known resource of China. Oil has never been produced in large quantities and most of the potential oil fields are unexplored. However, recent development in Kansu, Szechuan and Manchuria has given excellent results and petroleum production in China is expanding.

According to the present knowledge, there exist in China seven petroliferous provinces, namely, the North Kansu Basin, North Shensi Basin, Szechuan Basin, Tsungari Basin, the Tarim Basin, North Manchuria Basin and East Jehol Basin. The Kansu field has been proved capable of commercial production. Both the Szechuan and Shensi basins have been shown to be of some importance collectively by the finding of small fields. The existence of oil in Tsungari and Tarim basins in Sinkiang province has been known for many centuries and the oil belt south of Tihua is the richest. In Manchuria the Japanese have drilled wells in Chalainor coal field in Heilungkiang province and considerable oil has been produced in East Jehol. It appears that China possesses a considerable amount of oil, which has been tentatively estimated at 1,620 million barrels.

Oil shale in China is a significant source of oil. Manchurian oil shale has been of great value to the Japanese during the war. The largest single deposit in Manchuria is the Fushun oil shale in Liaoning province. It has a reserve of 2,219 million barrels of oil. Many small deposits of oil shale are found in Heilungkiang, Kirin, Szechuan, Jehol, Shensi, Shansi, Kwangtung, Kwangsi and Hunan, making up a total reserve of 2,303 million barrels of shale oil for China.

Most of China's present production of oil comes from Manchurian oil shale, only a small portion is natural oil from Kansu, Shansi, Szechuan and Sinkiang. These are of little significance in the petroleum production of the world.

Among the non-ferrous alloy metals and various subsidiary metals needed in the manufacture of standard and alloy steel, China has substantial quantities of manganese, rich tungsten, tin and antimony resources far in excess of her needs. Manganese ore has been estimated at 22.8 million tons of 45-per cent metallic content. This is not large in comparison with world's principal producers, but is adequate to support a moderate steel and iron industry. At present, manganese is produced in Liaoning, Kiangsi, Hunan, Kwangtung and Kwangsi. The last province alone produced 120,000 metric tons in 1937, a quantity more than that required for the present small steel industry. Tungsten deposits of China are the richest in the world. They are chiefly in Kiangsi, Kwangsi, Kwangtung and Hunan. The total reserves of tungsten oxide for China are 2,231,140 tons and over 90 per cent is concentrated in Kiangsi. China's tungsten output has always been foremost in the world

production. In the last ten years it ranged from 7,998 to 17,895 tons of concentrate of 65-per cent tungsten oxide, representing approximately 40 to 60 per cent of the world's production. In the future neither Burma nor the United States and Bolivia, which have been the important producers, can seriously compete with the rich high-grade ore of China. As tungsten is especially valuable as an ingredient of high-grade steel, a ferro-alloy industry which has already been initially successful on a small scale will undoubtedly expand in the post-war China.

Antimony is another important mineral in China which dominates the world's market. Before the war, China annually supplied 14,000 to 20,000 tons of antimony oxide and regulus (antimony metal), equivalent to 60–80 per cent of the world total. With the difficulty of export during the war, China was still able to produce 15,146 tons in 1937. Antimony ores are produced in Hunan, Kwangsi, Kuiechow, Kwangtung and Yunnan provinces. Hunan possesses the richest deposits constituting 88 per cent of China's antimony reserves which have been estimated at 4,223,040 metric tons of metal. It is reasonable to assume that the reserves will be considerably increased when increased export in post-war time pushes the exploitation of ores in the less known areas such as Kwangsi and Yunnan. China's leadership in the antimony market is unshakable, but a measure on stabilizing production and regulating export in conformity with the program of strategic-mineral conservation is urgently needed in the future.

China is also rich in tin ores. The workable tin deposits are mainly in Yunnan and Kwangsi. Small placer deposits have also been worked in Kwangtung, Kiangsi and Hunan. The latest conservative estimate of China's tin reserves is 1,873,370 tons metal, of which Yunnan deposits form the bulk. Tin production of China ranks fourth in the world output, being exceeded by Malaya, the Netherlands East Indies, and Bolivia. The peak production was 14,251 tons in 1938. Production in recent years has declined to less than 10,000 tons due to the difficulty of export.

The domestic supply of the base metals, copper, lead and zinc, has been inadequate in the past due chiefly to the undeveloped condition of most of the deposits and subordinately to the lack of fabricating plants. But the wide occurrence of copper deposits in almost every province of China is noteworthy. For the evaluation of such numerous deposits, extensive exploration is of course needed but the picture of the most important that lie in Yunnan, Sikang, Kueichow, Szechuan and Kirin is fairly clear. The recent estimate of copper reserves for these provinces is 2,893,350 tons, about half of it in Yunnan and Sikang. War-time exploitation of copper deposits in southwestern China increased the pre-war production from about 500 tons to 1,428 tons in 1939. China's annual consumption of copper is approximately 10,000 tons. With available reserves in these mines, China's production can step up easily to the goal of self-sufficiency in a relatively short period.

Lead, zinc and silver deposits of China have a similar pattern of distribution to the copper deposits. In fact, the important copper deposits in Kirin produce both lead and zinc and in southwestern China those of the different metals are fairly close to one another. The richest deposits of lead, zinc and

silver are in Liaoning, Kirin, Hunan, Kwangtung, Yunnan, Sikang and Kueichow. An apparently large belt of such deposits has recently been found in Sinkiang and many others in central and coastal China. The known reserves of high-grade lead and zinc ores in China are not great. A tentative estimate of lead reserves of 615,900 tons and zinc, 494,800 tons credits, Manchuria with more than 50 per cent of both metals. However, Hunan was by far the leading producer before the war, supplying annually about 5,000 tons of lead and 20,000 tons of zinc, while China's consumption was about 7,000 to 10,000 tons of each metal. The situation of lead and zinc is therefore not a matter of supply like copper but of lack of fabrication and manufacturing of finished products which were entirely imported through exchange of lead and zinc raw metals and concentrates. The post-war program demands the establishment of a large-scale smelting and fabrication industry as well as extensive exploration.

The quicksilver resources of China are considerable. The important quicksilver deposits are found within a belt extending from the border of Kueichow and Hunan southwestward to the east of Yunnan. The chief producing center is in Kueichow. Owing to the inefficient distillation and small-scale operation in widely scattered areas, the production has been small and the deposits are not well developed. Under the impetus of increased demand during the war, output has been greatly increased. Further development appears justified for this largely depleted important world resource.

Although the production of gold has little bearing on the industrialization, it provides the basis of foreign exchange which permits the import of machine tools. The size of the gold reserves of a nation determines its rank in international trade. China's most outstanding gold deposits lie in North Manchuria near the Siberian border, on the northeast seaboard of Hopeh and Shantung, in the northwestern Sinkiang at the foot of Altai Range, along the Tibetan borderland of Sikang and Szechuan and along Sikiang (West River) in Kwangsi. Gold is found largely as placer deposits and to a small extent in quartz veins. The gold placer deposits of North Manchuria and the lode ore of the Altai Range have been worked extensively. Gold production in the Tibetan borderland has increased in recent years. The total gold production in 1934 was 162,160 troy ounces while that for the southwestern region in 1939 amounted to more than 85,000 troy ounces. With government encouragement and introduction of mechanical processing, a production of 1,000,000 troy ounces for China should be attained within five years. The better working conditions in the southwest may help that region to overshadow the extensive deposits of the northeast and northwest.

As general industrialization progresses in China, some of the rare minerals will become increasingly important in industry. China produces a small amount of bismuth and molybdenum in association with tungsten ores and more than 1,000 tons annually of arsenic from realgar deposits and as a by-product of tin mining. Nickel deposits with an estimated reserve of 290,000 tons ore of .5 per cent metal content have been found in Sikang province.

China has no important native sulphur deposits. The only source of the sulphur that is used in the chemical industry and in making munitions is

pyrite. The pyrite deposits of China are mainly of two types: concretions in coal series and hydrothermal veins near igneous intrusions. Practically all the pyrite deposits in North China belong to the first type. Occurrences of the second type are important in South China, especially in Hunan, Kwangtung and Sikang. The known reserves of vein deposits in China are tentatively 8,248,000 tons. The reserves of the concretion deposits in North China are several times greater. North China deposits have an important share in the pyrite production. China produced about 4,500 tons of pyrite in 1934, of which less than 600 tons came from South China. China's domestic production has been insufficient and is supplemented with an annual import of 2,000 to 3,000 tons of sulphur from Japan.

Among the light metals, the extraction of aluminum and magnesium from bauxite and magnesite has rapidly become important as a result of the growth of the aircraft industry. China has the largest magnesite reserves in the

TABLE 1.

KNOWN RESERVES OF IMPORTANT MINERALS IN CHINA.

(Metric tons.)

Coal	240,847,000,000
Iron Ore	1,484,000,000–1,821,000,000
Manganese Ore	22,839,000
Tungsten Oxide (WO_3)	2,231,140
Antimony (metal)	4,223,040
Tin (metal)	1,873,370
Copper (metal)	2,093,350
Lead (metal)	625,900
Zinc (metal)	494,800
Pyrite Ore (South China)	10,248,000
Fluorite	400,000
Alunite	1,784,000,000
Magnesite Rock	200,000,000–5,000,000,000
Phosphate (P_2O_5)	13,005,000
Oil Shale	2,303,333,960 bbls.
Oil	1,620,629,700 bbls.
Nickel Ore	290,000
Bauxite	882,000,000

world. The magnesite deposits of Liaoning have been estimated to contain 200 to 5,000 million tons, and yielded 401,000 tons in 1938. China has also extensive bauxite deposits in Liaoning, Shantung, Kueichow, Yunnan and Kansu with a total reserve of 882 million tons. The deposits in Liaoning containing 57 per cent alumina have been used for aluminum extraction. Alunite, which may be considered a secondary source of aluminum, is found in Chekiang, Fukien and Anhui provinces. At present the alunite is used for making alum. Total reserves of these deposits are 1,784 million tons. Large quantities of aluminum clay which may sometime be used as an aluminum source are found in Hopeh province.

In the non-metallic mineral group, China has large deposits of fluorite in Chekiang available for flux in metallurgy and for glass making; abundant kaolin, fireclay and salt, with substantial barite, gypsum and talc, for cement manufacturing and for chemical and construction uses. China has been the leading producer of talc and supplies clay of excellent purity. There will be

TABLE 2A.

MINERAL PRODUCTION IN CHINA.

Mineral	Unit	1934	1935	1936	1937
Coal	1,000 m.t.	32,724	—	—	—
Oil	bbls.	677,481	—	—	—
Iron Ore	1,000 m.t.	2,635	—	—	—
Pig Iron	1,000 m.t.	631	—	—	—
Manganese Ore	m.t.	2,629	30,600+	60,355+	120,000+
Tungsten (65% WO_3)	m.t.	6,305	7,998	10,083	17,895
Bismuth (40–60% Bi)	m.t.	73	—	—	—
Molybdenum	m.t.	1.5	—	—	—
Antimony	m.t.	16,326	18,501	17,038	15,146
Tin	m.t.	8,307	10,011	11,846	12,285
Arsenic (mainly oxides)	m.t.	1,206	—	—	—
Quicksilver	m.t.	.5	—	5.2	15.9
Copper	m.t.	525	345	984	1,056
Lead	m.t.	620	—	—	—
Zinc	m.t.	600	—	—	—
Silver	ozs.	121,504	—	—	—
Gold	ozs.	162,160	—	—	—
Sulphur	m.t.	4,464	—	—	—
Fluorite	m.t.	5,000	—	—	—
Barite	m.t.	9,500	—	—	—
Alum	m.t.	15,550	—	—	—
Kaolin	m.t.	965,000	—	—	—
Gypsum	m.t.	67,720	—	—	—
Magnesite	m.t.	75,660	134,220	191,568	331,000
Asbestos	m.t.	290	—	—	—
Talc	m.t.	75,360	70,572	50,499	48,240
Salt	m.t.	3,220,000	—	—	—
Saltpeter	m.t.	5,000	—	—	—

— Data incomplete, see production figures under each mineral.

a great market for asbestos, mica and quartz of which very little has so far been produced, and the demand for saltpeter and soda will also increase. Phosphate deposits of Yunnan are available for making fertilizer.

In short, China, with her immense coal and moderate iron resources is potentially an industrial nation. Her petroleum production may not become important for some time but her oil-shale deposits are considerable. Her manganese appears to be sufficient to meet requirements. She is rich in gold but poor in silver. She will have a large export of antimony, tungsten, tin, magnesite, talc, clay and possibly fluorite, mercury, and arsenic. With ade-

TABLE 2B.

MINERAL PRODUCTION IN CHINA.

Mineral	Unit	1938	1939	1940	1941	1942
Tungsten (65% WO_3)	m.t.	13,387	11,580	9,163	12,723	12,951
Tin	m.t.	14,251	13,023	10,686	8,691	7,269
Quicksilver	m.t.	18.4	14.3	—	—	—
Copper	m.t.	1,046	1,428	—	—	—
Magnesite	m.t.	401,000	—	—	—	—

— Data incomplete, see production figures under each mineral.

TABLE 3.

MINERAL PRODUCTS OF CHINA AND PRINCIPAL PRODUCING PROVINCES.

Product	Principal Producing Provinces	
	In order of Production (Pre-war)	In order of Reserves
Coal	Liaoning, Hopeh, Shantung, Shansi	Shansi, Shensi, Honan, Szechuan
Iron	Liaoning, Hupeh, Anhui, Shansi	Liaoning, Chahar, Hupeh, Szechuan
Oil	Kansu, Szechuan, Sinkiang	Sinkiang, Kansu, Szechuan, Shensi
Oil Shale	Liaoning	Liaoning, Kirin, Shensi, Kwangtung
Manganese	Kwangsi, Hunan, Kwangtung	Kwangtung, Kwangsi, Kiangsi, Hunan
Tungsten	Kiangsi, Hunan, Kwangtung	Kiangsi, Kwangtung, Hunan, Kwangsi
Bismuth	Kwangtung, Kiangsi, Kwangsi	Kwangtung, Kiangsi, Kwangsi
Molybdenum	Kwangtung, Fukien, Liaoning	Fukien, Chekiang, Liaoning, Kwangtung
Nickel	———	Sikang
Antimony	Hunan, Kwangsi, Kueichow, Kwangtung	Hunan, Kueichow, Kwangsi, Kwangtung
Tin	Yunnan, Kwangsi, Kiangsi, Hunan	Yunnan, Kwangsi, Kwangtung, Kiangsi
Arsenic	Hunan, Yunnan, Kwangsi	Hunan, Yunnan, Kwangsi, Kueichow
Quicksilver	Kueichow, Hunan, Kwangsi	Kueichow, Hunan, Kwangsi
Copper	Yunnan, Kirin, Liaoning	Yunnan, Sikang, Kirin, Kueichow
Lead, Zinc and Silver	Hunan, Yunnan, Sikang, Liaoning	Yunnan, Liaoning, Hunan, Sikang
Gold	Heilungkiang, Szechuan, Sikang, Hopeh	Sikang, Szechuan, Heilungkiang, Hopeh
Pyrite	Liaoning, Shantung, Shansi, Honan	Szechuan, Honan, Hunan, Kwangtung
Fluorite	Chekiang, Shantung	Chekiang, Shantung, Kwangtung
Barite	Shantung	Shantung, Kiangsi
Bauxite	———	Shantung, Liaoning, Kueichow, Yunnan
Alunite	Chekiang, Anhui, Fukien	Chekiang, Fukien, Anhui
Aluminum Clay	Hopeh	Hopeh
Kaolin and Fireclay	Hopeh, Kiangsi, Liaoning, Shantung	Hopeh, Liaoning, Szechuan, Kiangsi
Gypsum	Hupeh, Hunan, Shansi, Kwangtung	Hupeh, Hunan, Kiangsi, Kwangtung
Magnesite	Liaoning	Liaoning
Asbestos	Hopeh, Suiyuan	Suiyuan, Honan, Hopeh, Shantung
Talc	Liaoning, Shantung, Hopeh	Chekiang, Liaoning, Shantung, Hopeh
Graphite	Kiangsu, Suiyuan, Honan, Hunan	Honan, Suiyuan, Shantung, Hunan
Mica	———	Kiangsu
Quartz and Beryl	Suiyuan, Kiangsu	Suiyuan, Kiangsu
Corundum	Hopeh	Hopeh
Diamond	———	Shantung
Saltpeter	Hopeh, Honan, Kiangsu, Shantung	Kiangsu, Honan, Suiyuan, Kansu
Soda	Suiyuan, Shansi	Suiyuan, Shansi
Phosphate	Kiangsu	Yunnan, Kiangsu
Salt	Liaoning, Kiangsu, Shantung, Szechuan	Liaoning, Kiangsu, Szechuan, Shantung

quate water power an industry of aluminum extraction from her extensive bauxite will be greatly developed. With sufficient exploration copper, lead and zinc will be found adequate for domestic needs.

GENERAL STATEMENT ON COMMODITIES.

Coal.

Geographic Distribution.

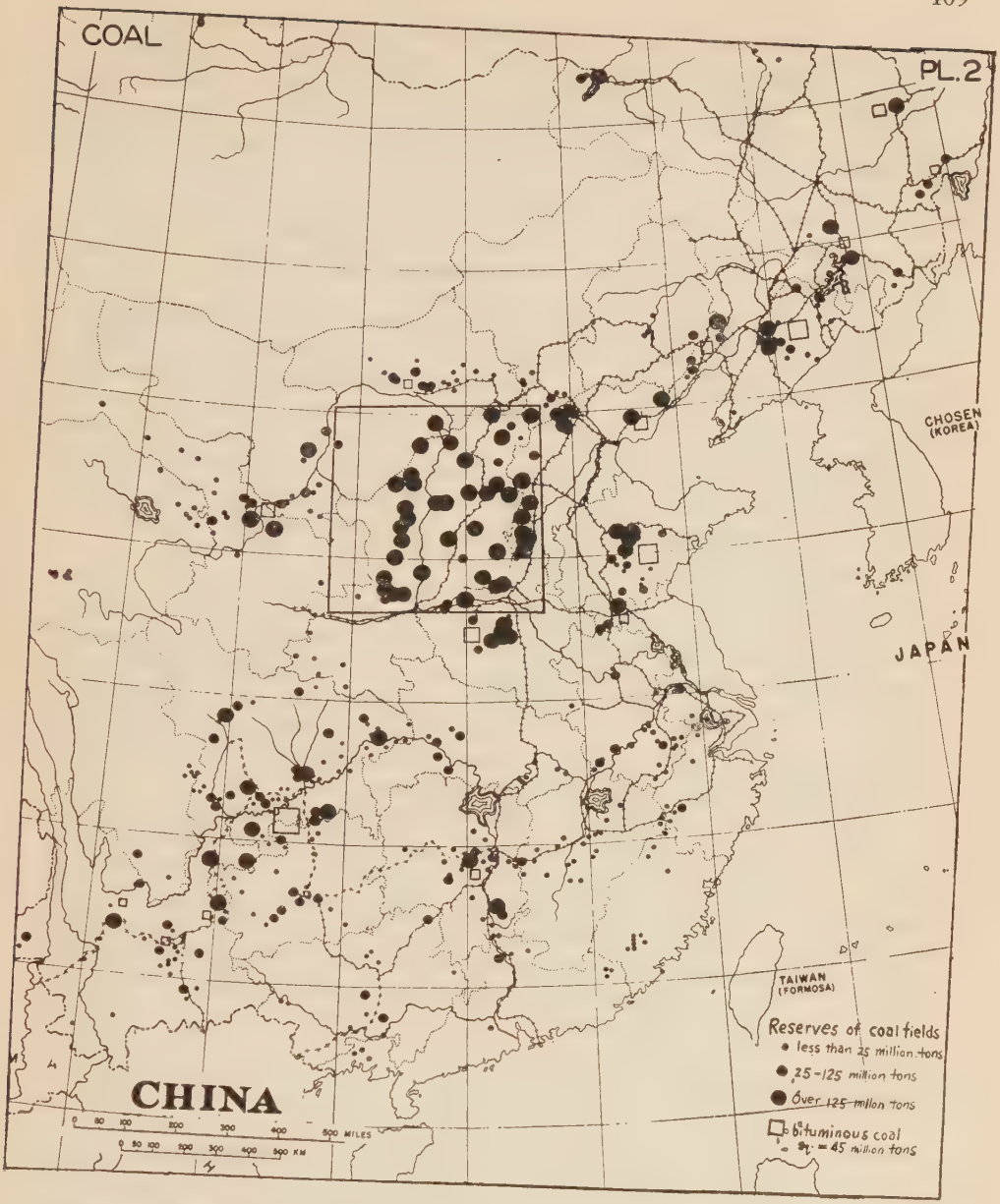
Coal deposits may be subdivided or classified in many ways, but this summary uses a simplified grouping of field, area and region. A *field* is a localized compact unit limited by natural features rather than trade practices. An *area* is a natural grouping of fields having coal of similar quality or geologic age. A *region* is a more extensive grouping of fields or areas on geographic or economic basis so they may be considered as a whole.

The coal deposits of China can be roughly divided into 6 regions: namely, the Manchuria region, North China region, Southeast region, Southwest region, Kansu-Ningsia region and Sinkiang region (Fig. 2).

Manchuria Region.—The Manchuria region is made up predominantly of the Jurassic basins of Jehol and Kirin and Tertiary basins of Heilungkiang, and the great coal area of southern Liaoning. The Heilungkiang Tertiary basins became of importance only in recent years when fuel was needed for railways. The coal is mostly lignite with a low percentage of ash. It is the only lignite region in China that has been worked on a commercial scale. However, as the coal carries a high percentage of moisture which requires special handling, it seems doubtful whether it will ever have more than a local value. The Jurassic basins of Jehol lie on the eastern flank of the mountain range of Great Hingan, and the Jurassic basin of Kirin is found on the eastern side of the Manchurian Highland which extends southward to form the Liaotung Peninsula. Jurassic coals in both provinces are high-volatile bituminous; some are coking and have been extensively mined. But, owing to the inferior quality of Jehol coal in comparison with that in Liaoning and the relative inaccessibility of Kirin coal to the present market, the coal industry in Jehol has been confined to local consumption and the large development in Kirin will depend on exporting through Korea.

Southern Liaoning is the chief storehouse of high-rank coal in the Manchuria region. The supply of this fuel has laid the foundation of the iron and steel industry and various manufacturing enterprises of the province. Liaoning coal comes from every coal series in China. It varies in age from Tertiary, Cretaceous, Jurassic, Permo-Carboniferous to Carboniferous. The Tertiary Fushun field is the largest single field in China, with a bed 10–120 meters thick, a unique feature not known elsewhere in the world. Due to local metamorphism the Fushun coal is high-quality bituminous coal in contrast to the Tertiary lignite coal of Heilungkiang. Carboniferous coal in Liaoning forms the bulk of the coking coal of Manchuria. Bituminous and low-volatile bituminous coals are produced in the less well developed Cretaceous, Jurassic and Permo-Carboniferous formations.

North China Region.—North China region includes all the coal fields north



of Tsinling Range and east of Ordos Plateau. The region includes the important Shansi-Shensi Basin, the Jurassic belt of Suiyuan and Chahar, and Carboniferous fields of North China Plain.

In the Shansi-Shensi Basin is the largest reserve of bituminous coal in China. It is of the greatest importance as the basis of China's heavy industry and general industrialization. The compact area of coal-bearing rocks has

the general form of a great basin, well defined on the eastern and southeastern margins. The axis of the basin runs from Tatung field, southward along the Fenho Valley to Tungkuan at the border of Shansi and Shensi. The rocks in the basin are disturbed by longitudinal faults along which the deeper strata have been elevated to near the surface, and consequently the coal beds in the middle part lie at shallow depths, so that the basin form is greatly modified. The coal of the Shansi-Shensi Basin is generally bituminous but shows considerable variation. There seems to be a progressive change from semi-anthracite and low-volatile bituminous at the southeastern margin to the high-volatile bituminous coal in the middle of the basin.

The Jurassic belt of Suiyuan and Chahar forms the southern margin of the Mongolian Plateau. It is a belt of intensive thrust faulting. The Jurassic coal series, which doubtless originally extended in unbroken sheets throughout the area, appears as small isolated strips and blocks. The Jurassic belt contains a greater variety of coal than any other province in China. The coal ranges from high-volatile bituminous to anthracite and the prevailing rank is low to medium-volatile bituminous. Good coking coal is found in the eastern part of the belt in Chahar, and several anthracite fields have been worked in the western part of Suiyuan province.

The coal fields of North China Plain are the principal producers in China. They are mainly fields of Carboniferous age distributed in North Honan and western Hopeh and in central Shantung. All the fields appear large in magnitude and as simple synclines or synclinal basins. The famous Kaiping basin and Yihsien field has a thick coal seam of 7–8 meters in a nearly flat-lying formation. The coal in the North China Plain is high-quality bituminous with almost uniform composition. It forms the largest reserve of coking coal in China, but is generally high in ash and sulphur.

Southeast Region.—Southeast region comprises all the fields in the mountainous area stretching from east of Kueichow Plateau to the southeast China coast. It includes virtually all the provinces south of Yangtze River below the Gorge, and is primarily a vast Permian region spotted with areas including the Jurassic coal series. Permian coal fields occur in two belts on both sides of the Nanling Range which runs northeasterly from the border of Hunan and Kwangtung through the boundary of Kiangsi and Fukien on the border of Anhui and Chekiang. The northern belt, spreading in a wider range to the Yangtze Valley, may properly be called Yangtze belt while the southern belt, which is much less important economically, is the coastal belt. Permian fields are mostly small in extent and complex in structure. The coal produced from these formations is mainly anthracite which makes the region unique in China. However, a few of the Permian fields in the Yangtze belt produce bituminous coal and in Hunan good coking coal has been found. A number of Jurassic fields are present in this region, but the large important Jurassic fields that produce coking coal are confined to the Yangtze belt. The principal centers of development are Anhui and Hunan.

Southwest Region.—Southwest region includes two distinct areas, the Szechuan Basin and the Yunnan-Kueichow Plateau. Szechuan Basin is mainly covered by Mesozoic rocks. The Jurassic coal series is found where-

ever anticlines and synclines are developed, although Permian coal beds, which lie underneath it, have also been worked. The Jurassic coal series produces good-quality coking coal but only from thin beds averaging less than .3 meter. The areal extent of this coal series and its proximity to the avenues of transportation and of rich agricultural land are responsible for the development of the fields.

Yunnan-Kueichow Plateau, on the other hand, is an elevated block of Mesozoic rocks. One single Triassic coal field and several Tertiary lignite deposits are found in central Yunnan, but the whole area is underlaid with Paleozoic formations of which the Carboniferous and Permian are coal bearing. Both Carboniferous and Permian produce coking coals though the quality is not equal to that of the North China region. Carboniferous fields are more important than Permian on account of the simple structure and thicker seams.

Kansu-Ningsia Region.—This region lies west of the Ordos Plateau but east of Takla Makan Desert. Coal series are found along the Alashan and west of Huangho and Nanshan ranges between Kansu and Tsinghai. Permo-Carboniferous coal-bearing rocks are widely distributed on the northern flank of the ranges, but they have not been exploited as much as Jurassic fields which are worked mainly on the southern slopes. Jurassic coal is generally higher in rank than Permo-Carboniferous coal which ranges from low-volatile bituminous to semi-anthracite and is high in ash and sulphur. As there is little market except for domestic heating the coal of this region remains largely undeveloped. The prospect of utilization, however, is more encouraging than in the Southeast region.

Sinkiang Region.—The coal resources of this region are largely unknown except in a few areas of high-rank Jurassic coal along the old caravan route leading from Kansu to Central Asia. The coal in this region is limited in the Tienshan Range between Tsungari Basin and Takla Makan Desert. At present, the known coal resources are not sufficient for a large industrial development. According to the available information on the geology of this region, a Permo-Carboniferous coal series should be present as it is in North China, though the coal beds may not be so numerous and so extensive as those of the North China region.

Geological Distribution.

The most important and productive coal beds in China are in the Permo-Carboniferous and next in importance in the Jurassic. The Permo-Carboniferous and Carboniferous are characterized by thick beds and simple structures. Jurassic coal is widespread and found in almost every province. These three systems produce the bulk of China's coking coal. Permian coal is found south of the Yangtze in strongly disturbed strata. It is important as it is semi-anthracite. Triassic and Cretaceous deposits are of minor extent while the Tertiary coals in Manchuria and Yunnan lie almost horizontal, close to the surface, and are the most easily and cheaply mined beds in China.

A study of the coal fields in China shows clearly that the factor controlling the character of the Paleozoic coal series is the presence or absence of crustal

movement. Regional metamorphism determines in large measure the rank of the coal, but the time factor is strongly revealed in the Mesozoic and Tertiary formations.

TABLE 4.

GEOLOGICAL AGE OF THE PRINCIPAL CHINESE COALS.

Age	Coal Field	Coal Region	Range of Coal[a]	Prevailing Rank of Coal[a]
Tertiary	Puchiopa	Southwestern	Lignite	
Tertiary	Chalainor	Manchuria	Lignite	Lignite
Tertiary	Fushun	Manchuria	High vol. bi.	
Cretaceous	Yuanpashan	Manchuria	Lignite	
Cretaceous	Shulan	Manchuria	Lignite	
Cretaceous	Pataoho	Manchuria	Sub-bi.	Sub-bi.
Cretaceous	Sian	Manchuria	High vol. bi.	
Jurassic	Wuchia	Manchuria	Lignite	
Jurassic	Peipiao	Manchuria	High vol. bi.	
Jurassic	Mishan	Manchuria		
Jurassic	Fushin	Manchuria	High vol. bi.	High vol. bi.
Jurassic	Talung	Northern China	High-med. bi.	
Jurassic	Pingsiang	Southeast	High-med. bi.	
Jurassic	Yuangtang	Southwest	Med. vol. bi.	
Jurassic	Skanchen	Kansu-Ninghai	Med. vol. bi.	
Jurassic	Santaoling	Sinkiang	Low vol. bi.	
Jurassic	Mentaokou	North China	Semi-an.	
Triassic	Ipinglang	Southwest	Med. vol. bi.	Med. vol. bi.
Triassic	Paikuowan	Southwest	Med. vol. bi.	
Permian	Changhsing	Southwest	High vol. bi.	
Permian	Ningsiang	Southwest	High vol. bi.	
Permian	Siangtan	Southwest	Med. vol. bi.	
Permian	Singsiang	Southwest	Low vol. bi.—semi-an.	
Permian	Fukwo	Southwest	Semi-an.	
Permian	Lungyen	Southwest	Semi-an.	
Permian	Hengshan	Southwest	An.	
Permian	Yunghing	Southwest	An.	
Permian	Chenhsien	Southwest	An.	
Permo-Carbon	Yihsien	North China	High vol. bi.	
Permo-Carbon	Chinghsing	North China	High vol. bi.	
Permo-Carbon	Kaping	North China	Medium vol. bi.	
Permo-Carbon	Tzepo	North China	Low vol. bi.	Med.-low vol. bi.
Permo-Carbon	Taiyuan	North China	Low vol. bi.	
Permo-Carbon	Pingting	North China	Semi-an.	
Carboniferous	Shakuotung	Manchuria	High vol. bi.	
Carboniferous	Penhsihu	Manchuria	Med. vol. bi.	
Carboniferous	Yentai	Manchuria	Med. vol. bi.	
Carboniferous	Hsuanwei	Southwest	Med. vol. bi.	Med.-low vol. bi.
Carboniferous	Kepaotsun	Southwest	Low vol. bi.	
Carboniferous	Niusintai	Manchuria	Semi-an.	

[a] High vol. bi.—high volatile bituminous
Sub-bi.—sub-bituminous
Med. vol. bi.—medium volatile bituminous
Low vol. bi.—low volatile bituminous
Semi-an.—semi-anthracite
An.—anthracite.

From the above table the following inferences can be made:

(1) The prevailing rank of Tertiary coal is lignite, with the exception of the high-volatile bituminous of Fushun. Lignite in China is not all Tertiary.

(2) Cretaceous coal in China comprises several ranks ranging from lignite to high volatile bituminous, but the prevailing rank of coal is sub-bituminous, and there is no sub-bituminous coal older than Cretaceous.

(3) Jurassic coal in China ranges from high-volatile bituminous to semi-anthracite. The age of Wuchia lignite so far as known has not been firmly established. The Mentaokou semi-anthracite is, of course, due to local metamorphism. Otherwise, the Jurassic coal shows high uniformity of rank all over the country and the prevailing type is high-volatile bituminous which makes the best coking coal in the country.

(4) Triassic coal has a rather limited extent and is found only in the southwest, and the rank of coal is uniformly medium-volatile bituminous.

(5) The prevailing ranks of Tertiary and Mesozoic coals show a uniform relation between the age and type of coal; from the Tertiary to Triassic there is a progressive change from lignite to medium-volatile bituminous.

(6) Permian coal in China is an outstanding example of the effect of regional metamorphism on the rank of coal. The coal ranges from high-volatile bituminous to anthracite, but semi-anthracite and anthracite predominate. It is interesting to note that the Permian coal in the southeastern region is an exception to the otherwise continuous correlation between age and coal composition.

(7) Permo-Carboniferous coal in North China includes all ranks from high-volatile bituminous to semi-anthracite, but medium-volatile bituminous to low-volatile bituminous are the most important ranks. The economic importance of Permo-Carboniferous coal of North China is as notable as the regional metamorphism of Permian coal in the southeastern region. It constitutes the bulk of China's coal resources and contributes a large percentage of bituminous coal. The differences between the Permo-Carboniferous and the Permian coal indicate differences in the geological history of North and South China.

(8) Carboniferous coals are found in the extreme northwest (Manchuria) and southwest. The Carboniferous coal series in Manchuria is in reality a part of so-called Permo-Carboniferous coal series. Here the differentiation between Permo-Carboniferous and Carboniferous is not yet so well established as in North China. The Carboniferous in the southwest is also important for supplying coking coals, and the prevailing rank ranges from low-volatile to medium-volatile bituminous.

(9) The lack of a simple relation between the rank of coal and its age in the Paleozoic coal formations can be explained only by the effect of regional metamorphism which in turn implies a complicated geological evolution.

Reserves and Production.

The reserves of coal in China, except for those of remote areas, are reasonably well known from the systematic study carried on by the Geological Survey of China.

These figures are extremely conservative. For those provinces in which details are given they represent more or less actual reserves. For coal in North China where thick seams are present, only seams greater than 1 meter have been taken into account. In South China where seams of .3 meter thick have been worked, the reserves are estimated to depth of less than 500 meters instead of the normal depth of 1,000 meters for coal in North China. Based on the present mining practice in China, the minimum thickness of coal minable

TABLE 5.

KNOWN COAL RESERVES IN CHINA.

(Million metric tons.)

Province	Given by GSC[1]				Present Operated Fields			
	Bi.	An.	Lig.	Total	Bi.	An.	Lig.	Total
Chahar	487	17		504	477.8	12.8	1.4	492
Suiyuan	396	58	22	476	379.3	74.2	17.5	471
Shansi	87,985	36,471	2,671	127,127	87,985	39,142		127,127
Shensi	71,200	750		71,950	71,200	750		71,950
Hopeh	2,090	981		3,071	1,803	939		2,742
Shantung	1,613	26		1,639	1,668	26		1,694
Honan	3,309	4,455		7,764	2,226	5,118		70,344
Sikang	501	3	27	531[2]	14.5	4.7	27.5	46.7
Kwangsi	80	114	106	300[2]	80	111		191
Szechuan	5,761	225		5,986[2]	2,615	399		3,014
Yunnan	946	11	1,384	2,341[2]	966.7	11	1,407	2,384.7
Kueichow	622	748		1,370[2]	270.5	63		333.5
Sinkiang	6,000			6,000	6,000			6,000
Kansu	1,500			1,500	479			479
Ningsia	322	166		488	222	161		383
Tsinghai	500			500	500			500
Hunan	721	1,043		1,764	459	367		826
Hupeh	280	160		440	121.3	113		234.3
Kiangsi	776	216		992	125	101		226
Anhui	300	60		360	170.4	134		304.4
Kiangsu	192	25		217	175	31		204
Chekiang	78	22		100	124	1		125
Fukien	105	291		396		69		69
Kwangtung	371	50		421	17.7	73.4	16.2	107.3
Liaoning	1,649	187		1,836	1,695	88		1,783
Kirin	986	2	155	1,143	636		160	796
Heilungkiang	619	6	392	1,017	588.9	6	377	971.9
Jehol	573	2	39	614	373		43	413
Total	188,770	47,281	4,796	240,847	181,372.1	47,795.1	2,049.6	231,211.8

[1] Hou, T. F., Spec. Rept. Geol. Surv. China, No. 5, p. 3, 1935.
[2] Chin, Y. H., Spec. Rept. Geol. Surv. China, No. 6, p. 2, 1941.

would be .3 meter instead of 1 meter for North China, but an ultimate depth of 2,000 meters may be reached in the future. A recalculation on this basis would therefore show great increase of coal reserves in China.

Comparison of these figures with the reserves of the world's principal coal producers, shows that reserves for Germany before 1918 down to 1,200 meters were 56,889 million tons and those for Great Britain, down to 4,000 feet including 1-foot seams, 135,111 million tons. The figure given in 1919 for the

United States was 3,535,690 million short tons, estimated on minimum thickness of 14 inches for high-rank coal and including also coal at depths between 1,000 or 2,000 meters.[1] China's available coal is more than 4 times greater than that of Germany and about twice that of Great Britain, but less than 7 per cent of that in the United States. These estimates are not strictly comparable since their bases are not identical, but on any basis reserves in the United States are many times those in China On the other hand, China has the only substantial coal reserves in the Far East. Australia has only 4,000 million tons of coal of possible commercial value, and the Dutch East Indies have about 1,417 million tons of which only 335 million tons are of known value. Japan's coal reserves of 8,000 million tons in 1913 are probably largely exhausted and Indo-China is known to have only 20,000 tons.[2]

Prior to the war, China produced about 32 million tons of coal a year. The output of coal in the United States in 1939 was about 405 million tons.[3] This would give roughly 3 tons per head of population which is 130 million in

TABLE 6.

COAL PRODUCTION OF CHINA.[1]

(1,000 metric tons.)

Year	Tonnage	Year	Tonnage	Year	Tonnage
1912	8,988	1920	21,260	1928	25,092
1913	12,800	1921	20,459	1929	25,437
1914	14,102	1922	21,097	1930	26,036
1915	13,417	1923	24,552	1931	27,245
1916	15,903	1924	25,769	1932	26,376
1917	16,902	1925	24,255	1933	28,379
1918	18,340	1926	23,040	1934	32,724
1919	20,055	1927	24,172		

[1] Bureau of Mines, China, Third World Power Conference, Washington, 1936, p. 3.

the United States. If China increases her production to that level for a population of 450 million, her reserve will last only about 200 years. If, on the other hand, China's consumption of coal increases from about 20 million tons to the present United States production, the total reserves will last 600 years. On the basis of the first assumption, which is more logical than the second one on account of the perpetually increasing rate of production required for industrial development, China's high-rank coal may be exhausted perhaps within 50 years which is also the time formerly estimated for the exhaustion of high-rank coal in the United States.[4]

The ratio of anthracite to bituminous coal in China is 1 : 4 while that for the whole world is 1 : 8. The provinces of Shansi, Shensi, Szechuan, Sinkiang and Liaoning lead in bituminous-coal production. Honan, Hunan, Fukien and Kueichow have more anthracite than any other coal.

[1] Campbell, M. R., The coal fields of United States, U. S. Geol. Surv. Prof. Paper 100, p. 25, 1929.

[2] Torgasheff, B. P., The Mineral Industry of Far East, 1930, Shanghai, p. 421.

[3] Mineral Yearbook, 1941, p. 901.

[4] Campbell, p. 26.

TABLE 7A.

COAL PRODUCTION IN CHINESE PROVINCES.
(In 1,000 metric tons.)

Province	1934				1935
	Bi.	An.	Lignite	Total	
Liaoning	10,548	90		10,638	10,976
Kirin	274		126	400	548
Heilungkiang	300		100	400	320
Jehol	335			335	322
Manchuria					
Total	11,457	90	226	11,773 (10,338)	12,166
Hopeh	6,353	1,386		7,739	7,028
Shantung	3,503			3,503	—
Shahar	132	70		202	196
Suiyuan	30	10	18	58	—
Shansi	1,532	1,168		2,700	—
Shensi	204			204	—
Honan	965	1,165		2,130	1,014
Northern Region					
Total	12,713	3,799	18	16,536	—
Kiangsu	266			266	—
Chekiang	250			250	—
Fukien		50		50	—
Kwangtung	57	281		338	—
Coastal Region					
Total	573	331		904	—
Hunan	306	583		889	—
Hupeh	42	416		458	—
Kiangsi	291	40		331	—
Anhui	506	127		633	—
Yangtze Valley					
Total	1,145	1,166		2,311	—
Szechuan	638	90		738	1,492
Sikang	24			24	24
Kueichow	40	33		73	260
Yunnan	70	25	20	115	160
Kwangsi	28	7	1	36	36
Southwestern Region					
Total	800	155	21	976	1,972
Kansu	99			99	—
Ningsia	11	4		15	—
Tsinghai	10			10	—
Sinkiang	100			100	—
Northwestern Region					
Total	220	4		224	—
Grand Total	26,914	5,545	265	32,724	

— Data incomplete.

TABLE 7B.

COAL PRODUCTION IN CHINESE PROVINCES.

(In 1,000 metric tons.)

Province	1936	1937	1938	1939
Liaoning	12,353	12,048	—	—
Kirin	680	735	—	—
Heilungkiang	470	680	790	—
Jehol	402	947	1,838	—
Manchuria				
Total	13,874	14,410	—	—
Hopeh	7,578	—	—	—
Shantung	—	—	—	1,700
Shahar	247	—	—	—
Suiyuan	73	—	—	—
Shansi	2,800	—	—	—
Shensi	—	—	—	—
Honan	2,667	—	—	—
Northern Region				
Total	—	—	—	—
Kiangsu	367	—	—	—
Chekiang	—	—	—	—
Fukien	—	—	—	—
Kwangtung	—	—	—	—
Coastal Region				
Total	—	—	—	—
Hunan	—	—	—	—
Hupeh	—	—	—	—
Kiangsi	—	—	—	—
Anhui	—	—	—	—
Yangtze Valley				
Total	—	—	—	—
Szechuan	1,518	1,618	2,203	2,552
Sikang	26	26	26	26
Kueichow	260	260	267	276
Yunnan	160	161	169	172
Kwangsi	38	38	40	35
Southwestern Region				
Total	2,002	2,103	2,705	3,061
Kansu	—	—	—	—
Ningsia	—	—	—	—
Tsinghai	—	—	—	—
Sinkiang	—	—	—	—
Northwestern Region				
Total	—	—	—	—
Grand Total	—	—	—	—

— Data incomplete.

The coal industry of China, though dating back to ancient time, began to take its shape only in the late nineties. Modernization has rapidly taken place since the establishment of the Republic in 1912. Many new mines were opened and some of the large coal mines in North China controlled by foreign money were redeemed with Chinese capital. The occupation of Manchuria by the Japanese forced the development of the coal industry in the Yangtze Valley. During the war the coal production in the southwestern region has been greatly increased for various industrial demands. The following table shows the rapid progress of China's coal industry.

In 1934, the large mines in the North China region produced about 50 per cent, Manchuria contributed about 20 per cent, and the remaining 30 per cent were produced by small non-mechanized mines in South China.

Export and Import.

The consumption of coal in China is very small, compared with the area and the population. Taking the average coal consumption of 20 million tons

TABLE 8.

IMPORT AND EXPORT OF COAL IN CHINA.

(In 1,000 metric tons.)

Year	Import[1]	Export		Excess of Export Over Import
		Manchuria[2]	Total[1]	
1929	1,918	4,010	7,066	5,148
1930	2,160	3,830	6,998	4,838
1931	1,753	4,260	7,361	5,618
1932	1,421	3,360	—	—
1933	1,979	3,738	—	—
1934	1,038	4,657	—	—
1935	—	3,559	—	—
1936	—	3,849	—	—
1937	—	3,420	—	—

[1] Organization of production processing and distribution of coal and coal products and liquid and gaseous fuels in China, 3rd World Power Conference, Washington, 1936, p. 9.
[2] Manchuria Year Book, 1941.

from the year 1925 to 1935, the consumption per head in cities was about .5 ton.[5]

China's production was in excess of her consumption. North China and Manchuria exported annually about 7 million tons of coal. In central China, along the Yangtze Valley, the coal production is not sufficient to meet the local demand. The deficiency must be met with coal from North China or from abroad. Owing to the shipping distances, coal from North China and Manchuria goes chiefly to Japan, while Japanese bituminous coal has a market in Central China. The coal imported by South China, mainly Kwangtung, is mostly anthracite from Indo China. China's export of coal has been in excess of import. With the development of transportation and industries, China

[5] Bureau of Mines, China, 3rd World Power Conference, Washington, 1936, p. 12.

will be able not only to have a better distribution for her own increasing demand, but also to supply the coal market of the Far East.

Oil.

Oil-producing and Oil-bearing Areas.

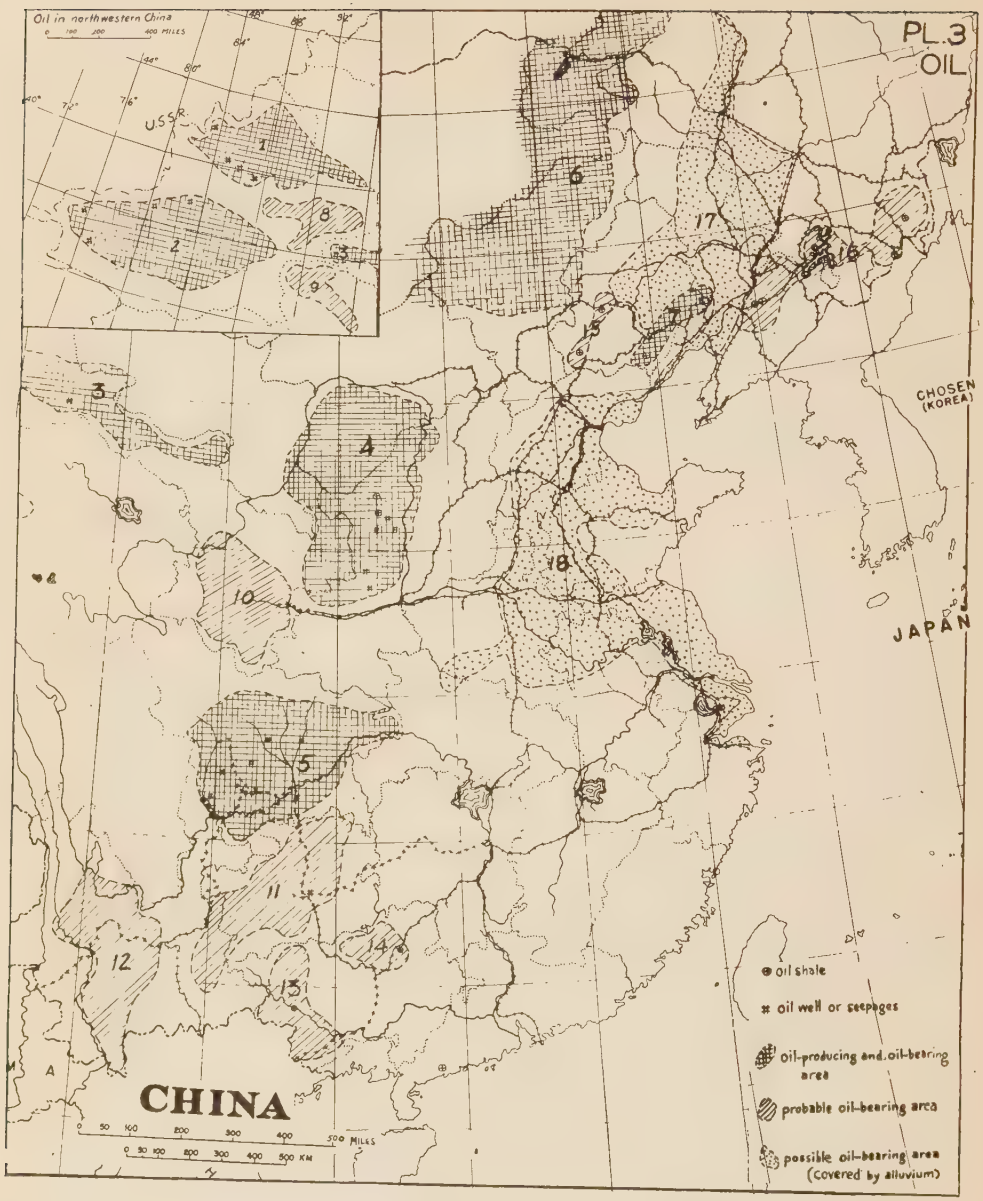
The oil fields of China, as known at present, occur in seven petroliferous provinces, namely, the Tsungari Basin, Tarim Basin, North Kansu Basin, North Shensi Basin, Szechuan Basin, North Manchuria Basin, and East Jehol Basin (Fig. 3).

Tsungari Basin (1) *and Tarini Basin* (2).—In the Tsungari Basin, a continuous oil belt has been prospected and proved to be capable of commercial production. The wells drilled in Tushantze on the southern border of the basin have each a daily yield of 75 to 224 barrels of crude oil. In the Tarim Basin, seepages are found at the northern and eastern margin but prospecting has not been started. The oil in Tsungari Basin is obtained in the younger Tertiary formations, and the oil prospects of the Tarim Basin are favored by the presence of marine Eocene beds in addition to the younger Tertiary formations. Whether the oil originated in the Cretaceous marine formation, as is the case in the Ferghana Basin of central Asia, or came from late Paleozoic beds is not certain.

North Kansu Basin (3).—Oil is produced in North Kansu Basin from Tertiary rocks of possibly Mio-Pliocene age. Two pay sands, 4 and 15 meters thick, have been penetrated in Laochuanmiao field at the northern margin of the basin and these yielded 32,595,200 gallons of crude oil in 1942. This field is to date the most promising one in China and is still being explored. It is possible that the oil originated in Permian or Jurassic formations and that more pay sands may be found in the strata between the source beds and the present shallow reservoirs.

North Shensi Basin (4).—North Shensi Basin was the earliest oil province prospected in a modern way. The petroliferous formations in this basin range from Upper Triassic to Lower Jurassic in age. There are three oil horizons each 2 to 3 meters in thickness. Prospecting was started in 1907 and many wells have been drilled since then but none of them is a large producer. North Shensi is a broad syncline which lacks prominent structures favoring accumulation of large oil pools. Cap rocks are absent throughout the vast areas. However, the production of Shensi oil was believed to be stray oil, that is, oil in bedding planes within the limits of meteoric circulation and in process of escaping. The small pools discovered after many dry holes had been drilled may be of some importance collectively.

Szechuan Basin (5).—Oil and gas have long been produced from the brine wells of Szechuan. Six oil sands have been discovered in formations ranging from Triassic to Cretaceous, while drilling for salt. Drilling for oil and gas was started in 1939. One well, penetrating from Jurassic to Triassic shale, produced 500,000 cubic feet of gas daily. Many failed to produce any oil. It is believed, however, that the failure of recent tests may have been due to technical difficulties or local structural irregularities. Szechuan has many prominent anticline and synclines favorable for oil accumulation.



North Manchuria Basin (6) *and East Jehol Basin* (7).—The North Manchuria Basin lies west of the Great Hingan Range and east of the Mongolian Plateau. It extends north from the northwestern part of Heilungkiang southwesterly to the northern part of Chahar. Oil was found in the Chalainor Tertiary coal field in 1940 and wells were known to have been drilled to a depth of 1,000 meters in 1941. To what extent the field has been developed

since is not ascertainable, but the presence of Tertiary basins similar to Chalainor fields along the foothills of Great Hingan Range and in the eastern Mongolia is well known. It is possible that these Tertiary oil-bearing strata are equivalent to the formations that yield commercial oils in Kansu. Oil in East Jehol Basin was found in the Jurassic coal formation. Drilling has been attempted near Fuhsin and considerable oil was being taken out in 1941. Although information on the actual development of this basin is not available, the possibility of its being a productive area is indicated by the occurrence of the Jurassic formation which has produced oil in the North Shensi and Szechuan basins, and by the presence of oil shale of Mesozoic age in the southern part of the basin, which is also a common feature in other oil provinces.

Probable Oil-bearing Area.

Since oil in China occurs chiefly in Mesozoic and Tertiary strata, such formations in regions other than those previously mentioned are not to be considered as absolutely non-oil-bearing, even though actual indication of oil has not been found. Such places are designated as probable oil-bearing and are separated into areas according to the general structural conditions.

Turfan Basin (8).—In Turfan Basin, which lies between Tsungari Basin and Tarim Basin in Sinkiang, both Mesozoic and Tertiary formations are found. These formations are comparable lithologically to those in the Tsungari and Tarim Basins, and a rich asphalt deposit has been discovered recently, though its exact stratigraphic horizon is not known. The Turfan Basin, like the Tarim Basin, is situated on the southern slope of Tienshan Range and is structurally analogous to the Tsungari Basin on the northern side of the range. It is possible that seepages of oil will be found around the edge of the basin with intensive search.

Tsaidam Basin (9).—Tsaidam Basin is a broad depression situated on the southwestern side of Nanshan Range which separates it from the North Kansu oil basin. A Tertiary formation is known to occur at the northern edge of the basin, and the possibility of its extension southward under the vast depression is still a problem which can be solved only by drilling. Comparison with the Tertiary beds in North Kansu, where commercial oils have been produced, and the strikingly similar regional geology, favor the possibility of finding oil in the basin.

South Kansu Basin (10).—The oil prospects in South Kansu Basin are based on the facts that Late Mesozoic and Early Tertiary formations of that area show close similarities in lithological character with those in Szechuan oil basin, and that separation of South Kansu Basin from Szechuan Basin by the Tsingling Range began in late Tertiary time. However, it should be emphasized that brine which carries oil and gas in Szechuan is not found in Mesozoic formations in South Kansu Basin, though salt is produced in Tertiary rocks. The Szechuan Basin assumed its present form at least in the early Mesozoic time while the age of basin forming in South Kansu is still uncertain. Present knowledge indicates that the petroliferous formations are

probably present in South Kansu; further speculation on the subject is not warranted without detailed investigation.

Northwestern Kueichow (11) is underlain with Permian and early Mesozoic formations. Oil-impregnated beds have been found in Triassic limestone southwest of Kueiyang. Because of flat-lying beds in which seepages are found, the early attempt to find commercial pools in this formation failed, but it is reasonable to assume that detailed investigation may reveal favorable locations for oil exploration. Western Yunnan (12) is another probable area, for red beds ranging from Triassic to Tertiary are well developed. The Lower Triassic formation in this province is believed to be of marine origin, as in the Szechuan Basin, while Tertiary sandstones that afford good reservoirs are present. In Kwangsi, oil-shales are found in the Nanning Basin (13) and Kueilin area (14). The oil shales in Nanning Basin are thick Tertiary beds in which lignite deposits have been worked. The age of oil shale in Kueilin area is not definitely known, but Permian and Jurassic coal series are known to have been worked in this area. In view of the close association of oil-shales with oil fields in China, these are designated as probable oil-bearing areas. Similar cases are found in western Jehol (15) and southeastern Manchuria (16), where Tertiary coal fields in which oil shales are found, have been extensively mined. These Tertiary beds are generally flat-lying or have gentile dips. Where structures are suitable, finding of oil pools in depth is not improbable.

Possible Oil-bearing Areas.

In studying the oil occurrences of Western Pacific areas, it is interesting to note that both in Sakhalin and in Japan oil is found along the coasts in rocks of Neogene age. China has extensive flood plains covered by alluvium along the coast; these are the South Manchuria Plain (17) and North China Plain (18), but the existence within them of marine Neogene rocks is so far not known. However, Miocene lacustrine deposits of small extent containing diatomite have been found around Linchu in Shantung province. These Miocene beds indicate that this coastal region was occupied by many isolated depressions during later Tertiary time, and that abundant organisms, such as diatoms, fishes and various plants, flourished in a warm climate. The conditions seem to have been favorable for preservation of such organisms and for generating oil in the sediments of the larger depressions.

It is generally believed that China has had a sinking coast in the Quaternary and that the alluvial deposits in the coastal plains are quite thick. The records of drilling water wells in Tientsin and Shanghai show gravel beds at a depth of over 270 meters. It is highly possible that Neogene beds may be revealed below the alluvium by deep test. Where structure is favorable, a commercial quantity of oil may occur.

Oil Reserves.

Owing to the incompleteness of our present knowledge, the oil reserves of China, though they may not be small, cannot be estimated with any degree of accuracy. Information on the oil fields classified as probable and possible

is too meager to warrant any estimation at present, but the fields in the oil-producing areas have been tentatively appraised by various investigators. The following table shows the amount of oil that can possibly be obtained in the present oil-producing areas. Since practically all the oil fields are largely undeveloped, the saturation method on a simple basis is used in the estimate. The factors considered are areas of the oil-producing sand, the specific gravity of the oil and the porosity. In the absence of actual determination, porosity is assumed to be 10 per cent in every case.

TABLE 9.

PRESENT ESTIMATE OF OIL RESERVES OF CHINA.

(42-gallon barrels.)

Sinkiang	844,200,000[1]
Kansu	150,000,000[2]
Shensi	16,400,000[3]
Szechuan	600,000,000[4]
Manchuria	10,000,000[5]
	1,620,600,000

[1] Hsieh, C. Y., Petroleum resources of China, Geol. Surv. China, Bull. 30, 1937, pp. 53–66.
[2] Sun, C. C., Report of National Resources Commission, 1940.
[3] Hsieh, C. Y., op. cit.
[4] China Handbook, 1937–1943 (estimated by Geological Survey of China).
[5] Estimate.

Shale Oil.

China possesses large deposits of oil shale in the provinces of Heilungkiang, Jehol, Kirin, Liaoning, Szechuan, Shensi, Kwangtung, Kwangsi and Hunan. The Fushun oil shale in Liaoning, the largest accumulation of all, has been worked by Japanese, while the others remain unexploited. All the recognized deposits appear close to the surface and can be cheaply mined. The Fushun oil shale, which lies just above the coal beds, is stripped by the open-cut method together with the coal, and the cost of mining is very low. The oil extraction plant at Fushun reportedly produced 360,000 tons of oil in 1939. The following table gives the locations of oil-shale deposits, their oil content and their approximate reserves.

Coal Hydrogenation.

Although the cost of production of oil from shale is appreciably lower than from coal, coal hydrogenation has been in operation in Manchuria since 1938. Bituminous coals of the Fushun, Sian and Shulan fields have been successfully used. China has a great surplus of bituminous coal but imports a large amount of oil from abroad. If hydrogenation proves economical under normal conditions, there will be a great field open for China to make up her oil deficiency. The existing Manchurian plants could possibly be kept for operation. Whether or not new plants can be established elsewhere depends on the progress of natural-oil production and the availability of large hydro-electric power which is required for coal hydrogenation. The prospect of hydrogenation may not be very promising in the near future, so long as

TABLE 10.

SHALE OIL RESERVES OF CHINA.

	Reserves of Oil Shale (1,000 tons)	Oil Content (%)	Oil Reserves (42-gallon barrels)
Heilungkiang	1,182,000	.2–1.4	74,000[1]
Kirin	50,000,000	15.5	58,125,000[2]
	6,000,000	5	2,250,000[3]
	2,000,000	10	1,500,000[3]
Liaoning	4,932,000,000	6	2,219,400,000[4]
	132,000,000	2	19,800,000[5]
Szechuan	2,000,000	4–43 (gals. per ton)	1,000,000[6]
Jehol	Not estimated		
Shensi	4,881,000	3–7	725,000[7]
Shansi	Not estimated		
Kwangtung	825,000	7–8	453,800[7]
Kwangsi	20,000	4	5,600[7]
Hunan	Not estimated		
			2,303,333,400

[1] Sawai, T. and Haraguti, K., Geol. Inst. Manchuria, Bull. 88, 1937, pp. 77–83.
[2] Nisida, S., Geol. Inst. Manchuria, Bull. 99, 1940, pp. 27–31.
[3] Sakamoto, T., Geol. Inst. Manchuria, Bull. 88, 1937, pp. 62–63.
[4] Uwatoko, K., Jour. Faculty of Science, Hokkaido Imperial Univ. Ser. Geol. and Min. vol. 1, 1931, pp. 115–203.
[5] Sakamoto, T. and Matuda, K., Geol. Inst. Manchuria, Bull. 88, 1937, p. 13.
[6] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941, p. 133.
[7] Hsieh, C. Y., Geol. Surv. China, Bull. 30, 1937, p. 66.

natural oils of low price are abundant in the world market, but the process remains as a last resort.

Production and Consumption of Oil.

Oil production in China has been small and present consumption depends largely on imports. Formerly kerosene formed the greater part of the imported oil products, but the import of gasoline is increasing. In the following tables, the partial production of oil from 1931 to 1942 and pre-war consumption in China are shown.

Iron.

Geographical Distribution.

Enough information is available to show the geographical distribution of the large iron-ore deposits in China. The works of F. R. Tegengren[6] and C. Y. Hsieh[7] give detailed descriptions of practically all the important iron deposits in China especially those of North China and the Yangtze Valley. The recent geological investigation by the Geological Survey of China in the Southwest region has added a great deal to the nation's known iron resources, as well as to the general knowledge of the iron occurrences in that region.

The following table shows, in quantities and percentages, the geographical

[6] Tegengren, F. R., Iron ores and iron industry of China, Geol. Surv. China, Mem. Ser. A, no. 2, 1921–1923.
[7] Hsieh, C. Y., Geology of the iron deposits in the Lower Yangtze region, Geol. Surv. China, Mem. Ser. A, no. 13, 1935.

TABLE 11.

PRODUCTION OF MINERAL OIL IN CHINA.

(In barrels of 42 gallons.)

	Shensi	Kansu	Szechuan	Sinkiang	Hopeh[c]	Manchuria
1931[a]	592	100	144	300	1,593	449,747
1932[a]	418	—	400	—	1,500	515,707
1933[a]	315	—	400	—	2,482	633,516
1934[a]	309	—	400	—	1,925	674,868
1935[b]	—	—	—	—	—	895,200
1936[b]	—	—	—	—	—	917,580
1937	—	—	—	—	—	—
1938	—	—	—	—	—	—
1939	—	—	—	—	—	—
1940[d]	—	586.5	—	—	—	—
1941[e]	—	5,139.2	—	—	—	—
1942[e]	—	43,460	—	—	—	—

[a] Hou, Spec. Rept. Geol. Surv. China, no. 5, p. 158, and 348, 1935.
[b] Manchuria Economic Yearbook for 1938, pp. 92–94, Tokyo, 1939.
[c] By-products from coke oven.
[d] China-at-war, June 1941, p. 34.
[e] China Handbook, 1937–1943, New York, p. 484.

distribution of the iron ores in China. To facilitate comparisons, the iron content of the principal deposits of each province is also shown. For convenience, the discussion of these estimates will be taken up by regions based on distribution (Fig. 4).

Manchuria has the largest reserves. Of the four provinces, only Liaoning and Jehol possess workable ore, but the reserves of low-grade iron ore in Liaoning are of such a magnitude that it stands in rank among all the provinces of China. Reserves amounting to thousands of million tons have been estimated by Japanese geologists. Estimates have also been carefully worked out by the Geological Survey of China and are acceptable for the known ore. The reliability of the larger figure for the workable ore depends largely on

TABLE 12.

IMPORT OF PETROLEUM PRODUCTS TO CHINA.[1]

Year	Kerosene, U. S. Gallons	Gasoline, U. S. Gallons	Lubricating Oil, U. S. Gallons	Liquid Fuel, Tons	Grease, Piculs*	Asphalt, Piculs*
1925	258,570,591	8,823,511	7,084,593	95,823	17,081	—
1926	232,991,961	12,797,271	9,025,798	133,728	31,109	—
1927	163,969,137	13,903,446	8,099,514	156,546	17,726	—
1928	262,792,609	20,041,590	12,384,563	221,668	21,748	—
1929	239,263,293	28,644,358	13,676,104	183,909	29,087	—
1930	185,608,596	59,725,052	13,029,535	151,093	24,300	—
1931	171,140,380	29,754,655	10,394,293	227,336	22,482	—
1932	145,918,794	24,114,506	8,277,167	234,660	14,585	152,186
1933	187,261,165	31,281,601	11,156,051	336,064	15,870	155,588
1934	119,004,015	39,654,070	11,173,292	408,694	21,246	219,865

[1] Organization of production, processing and distribution of coal and coal products and liquid and gaseous fuels in China, 3rd World Power Conference, Washington, 1936.

* 16.5 piculs = 1 metric ton.

the success to be attained in using low-grade ore in that region. The economy of smelting the low-grade ore of Manchuria is open to controversy and must depend on the purpose for which the ore is exploited. It is reasonably assumed that if the lean ore can be profitably used, more iron ore of this type will be discovered. Consequently an increase of reserves would result. Pro-

TABLE 13.

RESERVES OF IRON ORES IN CHINA.
(Million metric tons.)

Province	Tonnage of Ore	Fe Content	% of the Total
Liaoning	883.5–1,221.5	Lean Ore: 26–45% Rich Ore: 50% +	
Jehol	7.0	50% +	
Total for Manchuria	890.5–1,228.5		60%
Chahar	92	48–60%	
Hopeh	42	29–44%	
Suiyuan	34.7	50–60%	
Shantung	30	60%	
Shansi	100	50% +	
Honan	13	60%	
Total for North China	311.7		21%
Kiangsu	25	50%	
Chekiang	7	32–60%	
Fukien	25	45–65%	
Kwangtung	6	44–64%	
Total for Coastal Region	63		4%
Hupeh	44.4	60–63%	
Hunan	19.9	38–62%	
Kiangsi	15	59–63%	
Anhui	22	48–61%	
Total for Yangtze Valley	101.3		7%
Szechuan	39 4	39–56%	
Sikang	14.9	55%	
Yunnan	15.7	50–67%	
Kueichow	47.5	42–60%	
Total for Southwest Region	117.5		8%
Grand Total	1,484–1,821		100%

duction in Manchuria has been steadily increasing since 1932. Manchuria has shown her capacity to supply the necessary iron and the conclusion is justified that she will continue to be a center of heavy industry in the post-war era.

North China ranks second in quantity of iron ore. Except for the low-grade ore of Hopeh, which is comparable with that in Liaoning, the ores are hematite of high grade. The well known Chahar ore, though high in silica content, is the best in this region on account of its large tonnage and easy accessibility. It may well compete with the high-grade iron ores in the Yangtze Valley because of its closeness to coking coal and its ease of recovery by cheap mining methods. The estimate of Shansi ore is complicated by the fact that much of the ore there is in sparsely scattered nests not suited to modern exploitation. Without extensive exploration, locations for efficient

mining cannot be readily selected. The enormous reserves estimated for the province are undoubtedly there, but they will probably not be used to the same extent as the Chahar ore.

The Southwest region stands third in reserves of iron ore. The measured ore tonnage is higher than the reserves for Yangtze Valley, but difficulties of transportation, particularly in Sikang, will make it less available for immediate exploitation. Although the largest reserves in this region lie in Szechuan, the best concentration for cheap mining is the ore in Kueichow. Besides, Szechuan ore contains a considerable portion of siderite which makes it as low-grade ore in contrast with high-grade hematite and magnetite ores in other provinces. Because of the relatively recent discovery of most of the important ores in this region, the estimate of the reserves has been carefully weighed, and the ore taken for calculation is within the limit of present mining practices. Iron ore is greatly in demand in this region; all the reserves could eventually be taken out.

The early iron industry of Yangtze Valley is well known. The region ranks fourth in reserves and has the largest concentration of high-grade ore. The ores of Hupeh, Kiangsi and Anhui, forming nearly a continuous belt, are all located at a short distance south of the Yangtze. Very good information is available on these ores. By careful investigation of the deposits already mined, the reserves of ore have been increased from early conservative estimates and future developments may give even higher figures. There is no doubt that all the ores will be used. Hunan ores are mainly bedded hematite. Exploration by drilling has revealed that the deposits are rather complex in structure. They can be mined only to supplement the ore near the Yangtze River.

The fifth rank in reserves goes to the coastal region. The ores in Kiangsu are the continuation of the ore belt of Yangtze Valley region. The iron sand in Chekiang and Fukien, though it has been used in the past, is not included in the estimate of reliable supply. Kwangtung has mainly manganese-iron ores and limonite. The potentialities of the region as a whole as the site of an iron industry are not great. The present outlook is that lack of good transportation will delay the normal development of this region.

As the map shows clearly, the iron-ore districts lie only in the eastern half of Chinese territory. This is due primarily to the lack of segregation and concentration of iron and secondarily, to the less extensive geological investigation in the western half. However, the northwest region, which contains practically no ore here classed as workable, may give some ore for local use, especially in the Altai Range of North Sinkiang. Iron ores are at present produced in 20 of the 28 provinces and about 81 per cent of the supply is in Manchuria and North China.

Types of Ore and their Geologic Distribution.

The iron ore of China has been classified according to the mode of occurrence by Hsieh [8] in five major divisions; the metamorphosed deposits, detrital, residual, sedimentary and magmatic deposits. For the sake of convenience

[8] Hsieh, C. Y., op. cit., pp. 163–191.

and because of their economic aspects, the detrital and residual deposits are combined into one group, concentration deposits.

Metamorphosed Deposits.—This group includes the deposits of Proterozoic age that have been subjected to intensive metamorphism. The enclosing rocks have become quartzites and mica schists. The ore occurs as extensive layers occupying a definite stratigraphic horizon. Two kinds of ores may be distinguished: the lean ore is a banded hematite containing less than 30 per cent iron and more than 50 per cent silica; the rich ore, intercalated with lean ore in the same formation, consists chiefly of magnetite with small amounts of specularite in large veins and pockets which show an iron content of 60 to 70 per cent. The largest ore body seen in Liaoning has a length of 150 meters and is 15 to 18 meters wide. The bedded nature of the lean ore is regarded as indicative of sedimentary origin. Enrichment has resulted from leaching by ascending thermal waters from igneous intrusions. This type of deposit has a wide distribution from southern Liaoning across the sea to northeastern Hopeh. Minor deposits have also been found in eastern and southern Shantung.

Sedimentary Deposits.—This group includes the bedded hematite ore in the Sinian (pre-Cambrian), the oolitic hematite in Upper Devonian, hematite concretions in the Lower Carboniferous coal series and siderite nodules in the Jurassic formation. The Chahar ore is the best example of Sinian ore. It occurs as beds in a series of slates and sandstones. The thickness of a single ore bed varies from 10 to 300 cm., while the aggregate thickness is about 1.5 to 3.4 meters. The ore is essentially hematite showing oolitic and stromatolitic structure with an iron content of 48–60 per cent and 11 to 18 per cent silica with an average of .12 per cent phosphorus. The oolitic hematite of the Upper Devonian is widely distributed in Hunan, Kiangsi and western Hupeh. The ore beds occur usually at the base of the Upper Devonian sandstone and shale. The best location contains three beds each with a thickness of 1 to 2 meters. The ore is of good quality with 50 to 63 per cent iron and about 10 per cent silica, but it is high in phosphorus. Hematite concretions in the Lower Carboniferous are found in northern and central China, with prominent examples in Shansi and Hunan. In Shansi, ore occurs more commonly at the bottom of the coal series, while in other provinces ore is found in higher horizons. The ore contains 50 per cent or more Fe and is high in phosphorus, up to .2–.5 per cent. The Jurassic siderite deposit has so far been found only in Szechuan. The nodules are small and scattered in a layer of .3 meter or more. The ore occurs near the coal seam or intercalated with it. The grade of ore is 30–40 per cent Fe.

Magnetite ores include the contact-metamorphic deposit of the Yangtze Valley and the hydrothermal deposits of the Southwest region. The contact-metamorphic deposits are best represented by the Tayeh ore in Hupeh and the Tungkuangshan ore in south Anhui. The ore occurs near the contact of granodiorite and limestone, forming irregular ore bodies with maximum dimensions of 90 by 680 meters. It is chiefly hematite with some magnetite. The iron content varies from 60 to 63 per cent. The hydrothermal deposits occur in more or less tabular form or as veins in sandstone, volcanic tuff,

shale and limestone. The ore mineral is chiefly hematite with small amounts of specularite and limonite. The grade of ore ranges from 42 to 67 per cent Fe with less than 10 per cent silica.

Concentration Deposits.—This group includes all forms of iron ores redeposited by circulating water, together with the bog ores that have been formed in swamps. The iron-manganese ores of Kwangtung and Yunnan, accumulated on mountain slopes and in caves, are good samples of residual deposits. Detrital deposits in the form of magnetite sand are widespread in Chekiang and Fukien, but have no economic value for a modern iron industry. Bog iron ore is only found in Kwangtung, where it occurs as tabular bodies with an iron content of 44–64 per cent.

Classified according to the types already outlined, the amounts and percentages of iron are shown in the following table.

TABLE 14.

IRON ORE OF CHINA BY TYPES.

(Million metric tons.)

		Percentage
Metamorphosed Deposits	962.5	65
Sedimentary Deposits	266.3	18
Magmatic Deposits	212.9	14.3
Concentration Deposits	42.3	2.7
	1,484.0	100

By considering the relation between geological time distribution and the type of ore, we get a picture of the important iron-forming epochs in China. The oldest iron-forming epoch seems to have been in Eoproterozoic time during which sedimentary iron beds were deposited and later metamorphosed and enriched. Then came the periods of Sinian, Upper Devonian, Lower Carboniferous, and Jurassic depositions forming the principal ores of sedimentary type in China. In the Tertiary, only bog ores were formed, while the Quartenary is the period favorable for accumulation of residual iron ore. The age of the magmatic deposits is uncertain, but they may be confined to the Late Mesozoic and Early Tertiary when igneous activity was pronounced.

Production and Consumption.

The demand for iron and steel in China has been constantly increasing since the latter part of the last century. Modern iron production was started in 1913 in Hupeh, using Tayeh iron ore. In 1915 another smelting plant was erected in south Manchuria for the utilization of the Miaoerhkou iron ore by a Sino-Japanese company. During the first world war the boom of the iron trade stimulated the exploitation of Chahar. In more recent years, small furnaces have been erected in Szechuan.

Iron ore has been produced in 16 out of 28 provinces of China, but only 6 provinces, Liaoning, Shansi, Chahar, Hupeh, Anhui and Szechuan, produced pig iron by modern processes, the rest being obtained in native furnaces. Be-

fore the war China produced annually about 2.5 million tons of iron ore and about 600,000 tons of pig iron. Steel production has been insignificant. Since 1935, production has been rapidly increased, especially in Manchuria. In 1937, the mining of Chahar ore, which had been stopped in 1919, was re-

TABLE 15.

IRON ORE PRODUCTION IN CHINA.

(In 1,000 metric tons.)

Province	1934	1935	1936	1937	1938	1939
Liaoning	1,134	1,478	1,904	1,029	—	—
Shansi	180	—	—	—	—	—
Chahar				500	—	—
Fukien	3	—	—	—	—	—
Kwangtung	30	—	—	—	—	—
Hunan	12	—	—	—	—	—
Hupeh	452	733	741	—	—	—
Anhui	480	—	—	—	—	—
Szechuan	70	—	—	—	—	—
Kwangsi	11	11	11	11	11	11
Kueichow	—	—	—	—	—	10
Yunnan	—	18	18	18	18	18
Sikang	—	—	—	—	—	—
Total	2,635					

— Information not available.

TABLE 16.

PIG IRON PRODUCTION IN CHINA.

(In 1,000 metric tons.)

Province	1934	1935	1936	1937	1938	1939
Liaoning	475	608	633	762	—	—
Shansi	60	—	—	—	—	—
Chahar	—	—	—	—	—	—
Fukien	1	—	—	—	—	—
Kwangtung	9	—	—	—	—	—
Hunan	5	—	—	—	—	—
Hupeh	29*	—	—	—	—	—
Szechuan	20	14	14	17	20	29
Kwangsi	3	3	3	3	3	3
Kueichow	x	—	—	—	—	3
Yunnan	x	4	4	4	4	6
Sikang	—	4	3	3	4	5
Total	631					

* Estimated. x Less than 1,000 tons. — Information not available.

sumed. The total amount of iron ore produced in the last few years cannot be determined, as records are not available. The following tables showing the incomplete statistics can only give the relative magnitude and distribution of the production.

China exported to Japan most of her iron ore produced from Yangtze Valley and her pig iron smelted in Manchuria. The home-made iron and the

imports of iron and steel manufactures supply her total consumption which has been extremely low for a country credited with a population of 450 million.

Outlook of Iron Industry.

Availability of Iron Resources.—Although China's iron resources are not great, they are sufficient to supply a moderate-scale steel industry considering their availability. Many factors are involved in the determination of iron-ore supply, but accessibility, mining conditions and quality of the ore are the most important.

The use of Manchurian ore, as shown by past production, is mainly determined by its closeness to coking coal, which alone suffices to offset poor mining conditions and the low quality of the ore. The Anshan group of ores in the southwest of Shenyang is convenient to Penhsihu and Yentai coking coal, and the Tunghua ore near the border of Korea to Wutaokiang and Tiehchangtze coking coal. The high-silica, low-grade ore of Manchuria requires special concentration before smelting, but this metallurgical problem has long been solved and the success of smelting is shown by the production ratio of low-grade ore to high-grade ore, 7:1, in 1940. The Tunghua group of ores containing 3 to 10 per cent manganese are self-fluxing and can be used to advantage. It is evident that the high cost of using low-grade ore is compensated by the low cost of transporting the even greater quantity of coking coal than that required for using high-grade ore. The decided advantage of proximity to fuel supply in Manchuria is analogous to the condition which permits the low-grade ore of the southeastern portion of the United States to compete with high-grade Lake Superior ores. The condemnation of Manchurian ore by some observers, on the ground that the Manchurian production was heavily subsidized primarily for military reasons, shows ignorance of the present tendency of using low-grade ore in the iron industry, and also misinterprets the function of subsidies which were used purely to promote increased production, that could not be obtained through the normal growth of the industry

The Chahar ore is decidedly superior in quality to Manchurian ore. The ore is best smelted with Tatung coal which has good coking properties and low sulphur content. The Tatung coal is only a short distance west of the ore and its reserves of 2,870 million tons are more than enough to smelt 92 million tons of Chahar ore. Therefore, the ore can be more cheaply smelted at the point of production than after shipment to the Peiping-Tientsin area. The advantages of its high-grade character and its proximity to coking coal would more than offset the higher cost of production by underground mining.

The Yangtze Valley, which has been the center of export of iron ore, will be the source of supply for steel plants in central China. The ores are of high grade, especially those in Hupeh and Anhui, and, with the exception of the bedded hematite in Hunan, are mostly suitable for open-cut mining. Coking coals for smelting such ores can be obtained by rail from central Hunan and western Kiangsi, or by Yangtze River from Anhui. The total ore available in this region is greater than the Chahar ore and can be used very profitably.

The ores available for immediate use in the southwest region are those in

Kueichow, southern Szechuan and Yunnan. Good coking coals for smelting have been mined in northeastern Yunnan near the border of Kueichow. The ores are of high quality, comparable to that in the Yangtze Valley, and are partly suitable for cheap open-cut mining. Sikang ores, though substantial in amount, are inaccessible at present and far from the source of coking coal.

The proposed iron-producing center near Canton in Kwangtung has not as great promise as the other districts discussed above. The iron ores available are the bog ores in Yunfu and the hematite ores in Fukien. The total quantity of ore known at present is less than 50 million tons, a quantity insufficient for large operations. However, the Hainan ore may be shipped in by sea, if this is proved economical, and additional imported ore may come from abroad. The method used for treating Yunfu ore in this center would be especially well suited to imported lateritic ores from the Philippines and bog ores from British Borneo. Coking coals for smelting can be obtained from fields on the border of Kwangtung and Hunan and the manganese ore of Kwangsi is close at hand.

The ores in Shansi have proved uneconomical for use on a large scale. Siderite ore in Szechuan and many scattered ore bodies in other provinces can only be considered as secondary supplies.

Foreign Iron-ore Supplies.—Owing to the abundance of fuel in China, certain foreign iron ores are so situated that they are considered practically a part of the available supplies. The most important of these sources of foreign supply are located in the Philippines, Netherland East Indies, Malay Peninsula and British Borneo. In these countries only limited quantities of coke can be produced, and iron ores are in great abundance.

The total estimated foreign supplies of ore accessible to mining and transportation, and so located as to affect the iron industry of China, according to present knowledge, are as shown in the following table:

TABLE 17.

ESTIMATED FOREIGN IRON ORES.[1]

(Metric tons.)

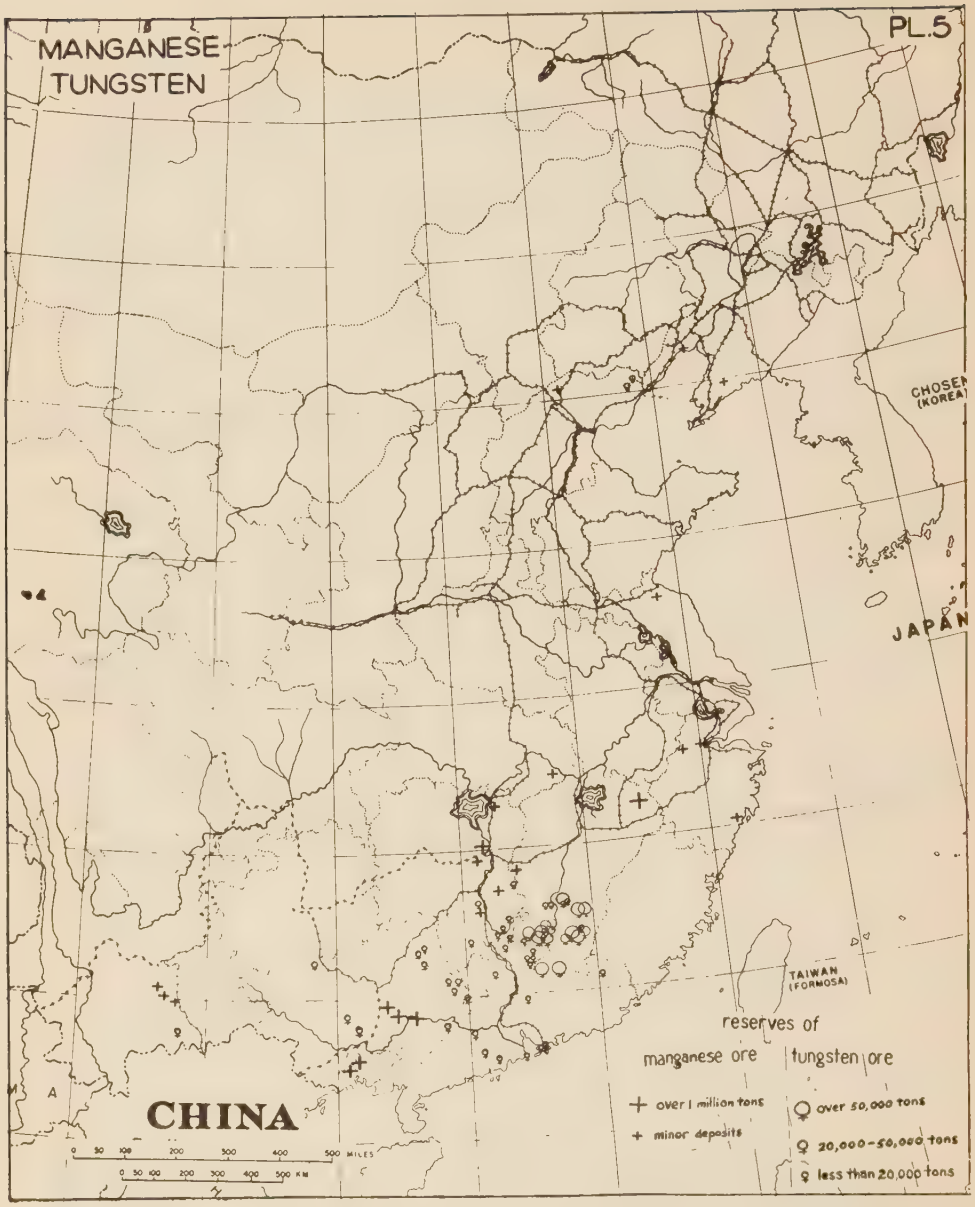
Philippines	200,000,000
Malay Peninsula and British Borneo	25,000,000
Netherlands East Indies	800,000,000
	1,025,000,000

[1] Tegegren, F. R. Iron ores and iron industry of China, Mem. Geol. Surv. China, Ser. A, No. 2, pt. 2, p. 431, 1924.

Manganese.

Geographic Distribution and Geologic Occurrence.—Important manganese ores are found in South China, south of the Yangtze River. Small deposits have also been worked in Shantung, Hopeh and Liaoning provinces. Among the provinces in South China, Kiangsi, Hunan, Kwangtung and Kwangsi appear to have large workable deposits (Fig. 5).

The ores are mainly sedimentary in origin, subordinately replacement lenses and residual deposits. The richest ore, confined to beds near the surface, consists of nearly pure psilomelane nodules and has a manganese content



of over 40 per cent. The low-grade ore, which ranges from 20 to less than 40 per cent manganese, is chiefly sandstone impregnated with psilomelane and pyrolusite. The Chungpuchai deposit in Kiangsi, one of the largest, contains ores of 40 to 50 per cent manganese in beds of 20 meters thick, in addition to the residual bog ores with a manganese content of 20 to 30 per cent. In Hunan, the most important Shangwutu occurrence has a productive bed

6 to 7 km. in length exposed in synclines and anticlines. In the Chinhsien deposits of southwestern Kwangtung, the ore is found as replacement lenses, in shale and sandstone, and contains 33 per cent manganese. But the rich residual ores in boulders and masses in the surficial red clay can be sorted to a grade of over 40 per cent Mn. The Kwangsi ores are mainly found as pyrolusite and psilomelane concretions in red clay.

In China, the supply of manganese is entirely obtained from manganese ore. Other sources such as manganese-iron ores, manganese-silver ores and manganese-zinc residuum, that have been used in other countries, have so far not received proper attention and are not included in this discussion.

Reserves and Production.—The reserves of the most important manganese deposits in China amount to 22,839,000 metric tons, of which Kwangtung deposits amount to 12 million tons. Kwangsi may have a reserve greater than the 3.6 millions tons given at present, as one large deposit was not included in the estimate. The reserves of the small deposits in Liaoning, Kiangsu, Chekiang, Hupeh and Hopeh together are given at 2 million tons.

TABLE 18.

ESTIMATED RESERVES OF MANGANESE ORE IN CHINA
(Metric tons.)

Province	Tonnage of Ore
Kwangtung	12,000,000
Hunan	1,739,000
Kiangsi	3,500,000
Kwangsi	3,600,000
Liaoning, Kiangsu, Chekiang, Hupeh and Hopeh	2,000,000*
Total	22,839,000

* Hou, no. 5, p. 5.

Production of manganese ore was first started in 1914 when the mineral had a good domestic as well as foreign market. When the steel plant in the Yangtze Valley was completed in 1928, Hunan ore formed the main source of supply. The ores in Kwangtung and Kwangsi were mined chiefly on a small scale, and the ores were shipped through Hongkong to the United States. The ores mined from Kiangsi were entirely shipped to Japan. Liaoning ores were used in Anshan Iron Works. In recent years the production has declined greatly due to the competition met in the world market and the decreased demand in domestic iron works.

Future Prospect of Supply.—Since most of China's iron ores are high in silica content and could be profitably treated in open-hearth furnaces, the high-grade manganese ore in South China would be of great value in this process. All the domestic production of manganese maintains a grade well over 43 per cent Mn which is more than that required for making ferro-manganese. Kiangsi ore is particularly good on account of its low silica content.

All the important manganese deposits in China can be cheaply mined by the open-cut method and some of them are rich enough to permit the shipping of large quantities without concentration.

For China to keep the pre-war production of high-grade manganese ore, say, 32,000 tons a year, exclusively for domestic use in post-war time, her steel industry must attain an annual capacity of approximately 4,800,000 tons of steel at the rate of 14 pounds of manganese in the form of ferro-manganese to 1 ton of steel. At such a rate of production, her present known manganese reserves would last more than 700 years.

The Kiangsi ore is readily accessible for export through Yangtze River to North China. This low-silica manganese ore is well suited for use in the smelting of the siliceous iron ore in Chahar and Manchuria. Both Hunan

TABLE 19.

PRODUCTION OF MANGANESE ORE IN CHINA.[1]

(In metric tons.)

	1931	1932	1933	1934	1935	1936	1937
Liaoning	650	60	750	700	600	355	—
Kiangsu	—	—	—	—	—	—	—
Hunan	11,000	(5,471) 12,000[2]	(227) 5,000[2]	—	—	—	—
Kwangtung	8,000	500	500	50	—	—	—
Kwangsi	12,000	15,530	8,773	1,000	30,000	60,000	120,000
Total	31,650	21,561	10,250	2,629	—	—	—

[1] Hou, Spec. Rept. no. 5, p. 202, 1935. — Information not available.
[2] Wong, W. H., and Hou, T. F., Cong. Int. des mines Paris, 1936.

and Kwangtung manganese ore would be profitably used in the Hunan iron work and Canton iron work respectively. The Kueichow iron work can only be supplied by Kwangsi ore through an overland route. Kwangtung ores are close to the southern coast; export is possible in case of surplus.

Tungsten.

Geographical Distribution.—Almost all the Chinese tungsten deposits are found in South China and are practically confined to what is commonly known as Nanling Range (Fig. 5). It is a rugged mountainous region trending SW to NE from southeastern Yunnan through northern Kwangsi, northern Kwangtung and southeastern Hunan to southern Kwangsi, and roughly parallel to the coast of South China Sea. It is a region characterized by intrusions of large granite batholiths in zones of intense and complex folding.

Tungsten deposits occur in all the provinces mentioned above, but are especially rich and abundant in south Kiangsi where the parallel mountains following axial anticlines afforded favorable structure lines along which the tungsten ores were emplaced. These deposits, therefore, appear in groups following the major structural units in this region of intrusions of granite batholiths. Kiangsi deposits that cover an area of approximately 36,400 sq. km. form the bulk of China's reserve of tungsten ores. The total tonnage of WO_3 content in tungsten ore in China has been estimated at 2,231,140 metric tons, while that in Kiangsi is 2,038,290 metric tons, more than 90 per cent of

the total. The southeastern Hunan area, where the important deposits of the province are found, is the continuation of Kiangsi deposits. The noted deposit in Tzehsing district is reputed to be the first tungsten discovered in China. The total reserve of Hunan deposits known at present is 19,000 metric tons of WO_3. In Kwangtung, tungsten deposits are widely scattered throughout the whole province from the northern part, which is virtually a part of the Nanling region, to the coast. Each individual deposit is small in comparison with those in Kiangsi and Hunan, but the numbers of locations that have been mined are considerable. In general, the deposits of Kwangtung are less known geologically, but the total reserves for this province have been tentatively estimated as 148,850 metric tons of WO_3. Tungsten deposits are found in two separate E–W zones in Kwangsi, one in the northern part and the other in the southern part of the province following roughly the trend of the Nanling Range. It should be emphasized that the tenor of tungsten in the Nanling deposits declines sharply towards the west and the Nanling Range, which is the storehouse of tungsten in the Kiangsi-Hunan section, becomes the site of tin deposits in the Kwangsi-Yunnan section. Genetically, tin ores in China are closely related to tungsten ores. The displacement of tungsten by tin in the western section is a problem that remains to be investigated. The fact is that in Kwangsi, placer ores are more prominent and richer than vein deposits. Up to the present, the reserves of tungsten ore including only those that have been mined amount to 25,000 tons of WO_3 content. Fewer deposits are found in eastern Yunnan and the reserves are not known.

TABLE 20.

ESTIMATED RESERVES OF TUNGSTEN IN CHINA.

(Metric tons.)

Province	Tonnage of WO_3 Content
Kiangsi	2,038,290
Hunan	19,000
Kwangtung	148,850
Kwangsi	25,000
Total	2,231,140

Ore Deposits.—The tungsten deposits of China fall in three types: pegmatite veins, replacement veins and hypothermal deposits. The pegmatite veins, containing the ore minerals wolframite or scheelite, cassiterite and molybdenite, occur as irregular dikes and pockets in small granite intrusions, or in marginal portions of batholiths. The ore-bearing pegmatites differ from the more productive hypothermal veins, which are intimately associated in their content of a larger amount of orthoclase and relatively insignificant amount of ore minerals. They also show less intense wall-rock alteration and generally have irregular shape. The replacement deposits are found in greisenized granitic rocks. The veins are associated with thick zones of greisen in the form of irregular patches, lenses, pockets and rudely tabular bodies. They occur in the upper portion of granite cupolas and usually carry as much cassiterite as wolframite. The greisen itself carries in places cassit-

crite only, and in other places small amounts of bismuthite and bismuth ocher. Hypothermal veins form the most productive type in China. They are well-defined tabular bodies filling the pre-existing fissures in either granite or the sediments near the granite. They are regular in strike and dip, and in lateral and vertical extension. A zonal arrangement of ore minerals in the vein is common. The bismuth minerals occupy higher horizons and molybdenite occupies lower horizons than wolframite in these veins. In places arsenopyrite is dominant and cassiterite seems to be richer in the upper horizons.

It is evident that the chief tungsten deposits in China are regular fissure veins. They are well-defined tabular bodies with flat walls and unvarying strike and dip. Locally irregular bodies are found, but they are comparatively rare and economically unimportant. Tungsten veins differ greatly in thickness and extent. Many are grouped together in sheeted zones. Maximum width is 3.5 meters but productive veins commonly range from .1 to .5 meter. Lateral and vertical variation in width is common, but usually wider veins maintain their width for long distances. Branching is not common and usually does not obscure the apparent regularity of the veins. The common veins are from a hundred to several hundred meters long; only a few small deposits are several meters to tens of meters long. The largest vein can be traced for a distance of one thousand meters. Mining has not proceeded far enough for the vertical range of this vein to be determined with any certainty. In some of the rich tungsten veins, ore has been mined to a depth of 300 meters below the highest point of outcrop. In some other deposits, workable ore has been obtained at depths of 60 to 70 meters. The vertical extent of veins in sedimentary rocks, in general, is greater than that of veins in granite.

No downward petering out of the ore content has been observed, but a few places, the topmost portions of such veins are poorer in wolframite and rich in bismuthinite. In other localities, molybdenite becomes abundant in the lower portion of the vein where wolframite decreases in amount. The tenor of the workable veins ranges from .5 to 4 per cent WO_3 with a probable average of about 1 per cent. Placers, though they exist, are generally small in extent and less important.

Mining and Production.—Active mining of tungsten began during the first world war when most of the principal deposits were discovered. Placers furnished most of the early output, but are now less productive than formerly. Lode mining, in spite of the large aggregate production, is mainly by crude methods. Small groups of miners work the veins by means of open-cuts, short tunnels and inclines. Hand drilling and black powder are used. Under favorable conditions, mining of this sort has extended to a depth of 150 meters. In Kiangsi, it was estimated that veins in sediments, though less numerous than veins in granite, yielded about 52 per cent of the provincial total, those in granite 44 per cent and placers 4 per cent. Kwangsi is the only province where large portions of the production came from placers which, at present, are treated by hand crushing, jigging and sluicing. The rough concentrates with 50 to 55 per cent WO_3 and a variable amount of tin are retreated. The wolframite and cassiterite are separated magnetically. Finally,

concentrates as shipped average about 65 to 69 per cent WO_3, .66 per cent Sn, and .14 per cent As.

China, starting during the first world war with a production almost nil, climbed up to about 85 per cent of the world production shortly after the war. From 1934 to 1938 inclusive, China yielded about 40 per cent of the world's tungsten. The average annual production of tungsten concentrate of 65 per cent WO_3 from 1939 to 1942 was 11,600 tons. In this period, the Kiangsi output amounted to about 77 per cent of China's total. Hunan produced about 9 per cent, and the remaining 14 per cent came from Kwangtung, Kwangsi and Yunnan in order of importance.

TABLE 21.

TUNGSTEN PRODUCTION IN CHINA.[1]

(Concentrate, 65% WO_3 in metric tons.)

	Kiangsi	Kwang-tung	Hunan	Kwangsi	Yunnan	China Total	World Total	Percentage Produced in China
1934	4,480	1,320	455	—	—	6,305	17,000	37
1935	5,000	—	—	437	200	7,998[2]	22,500[4]	35
1936	6,593	—	1,400	1,066	250	10,083[2]	22,457	44
1937	7,971	2,068	1,883	1,379	690	17,895[2]	24,867	50
1938	9,110	1,392	2,107	897	650	13,387[2]	39,607	33
1939	8,582	994	1,462	658	550	11,580[2]	—	—
1940	6,673	846	971	673	400	9,163[3]	—	—
1941	10,084	870	1,084	686	230	12,723[3]	—	—
1942	10,016	593	901	443	101	12,951[3]	—	—

[1] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941. Hou, T. F., Spec. Rept. Geol. Surv. China, no. 5, 1935.

[2] Mineral Yearbook, 1940.

[3] Morris, J. M., Chinese tungsten, Foreign Econ. Admin. Washington, 1943.

[4] Li, K. C., and Wang, C. Y., Tungsten, Amer. Chemical Soc. Monograph Ser. No. 94, 1943, p. 281.

Future Prospect of Supply.—China has the world's richest and most extensive tungsten deposits, but the tungsten-mining industry in China is still in its infancy. The future trend of world production and increasing competition among the principal producing countries require improvements in mining methods and processes of concentration. There has undoubtedly been large waste in picking ores, and low recovery obtained by simple gravity concentration. Systematic mining would greatly increase the production at costs that could compete with any tungsten production in the world. It is believed that for Kiangsi alone, a production of 16,000 tons of concentrate could easily be reached, which is approximately the equivalent of the world's annual prewar consumption. China can maintain such a rate of production for many years to come.

A tungsten industry is not existent in China. Although the manufacture of ferro-tungsten alloys has been experimentally carried on during the war, the bulk of the tungsten was exported as concentrates. Increased domestic consumption in the post-war era will help to balance and regulate the pattern of production and the irregularity of prices of tungsten in the world market.

Bismuth.

Bismuth production of China is entirely a by-product of tungsten mining (Fig. 6). Bismuth ores are found in the upper part of a tungsten vein of replacement type. Bismuthinite is the chief ore mineral, but native bismuth, and bismuth ocher also occur. Ore rich in bismuth, encountered in tungsten mining, is mainly hand picked and sorted separately. Only relatively few tungsten veins yield bismuth. At present, only three deposits in Kwangtung, one in Kiangsi and one in Kwangsi are producing. The annual output from 1931 to 1934 ranged from 20 to 130 tons of concentrate of 40 to 60 per cent Bi.

TABLE 22.

BISMUTH PRODUCTION IN CHINA.[a]

(40–60% Bi concentrate, in metric tons.)

	Kwangtung	Kiangsi	Kwangsi	Total in China
1931	120	—	10	130
1932	16	—	4	20
1933	8	30	7	45
1934	10	50	13	73

[a] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 5, 1935.

Molybdenum.

The molybdenite deposits in China (Fig. 6) occur in two types: as replacement and fissure-filling deposits in limestone associated with copper, lead and zinc ores, and as pegmatite veins in granite, associated with tungsten and bismuth ores. The first type is known in Liaoning province where it was produced as a by-product of copper, lead and zinc mining. The second type is found in Chekiang, Fukien and Kwangtung. The deposits in Chekiang and Fukien have been developed primarily for molybdenum while those in Kwangtung have been the by-product of tungsten mining. Among these producing districts in China, Fukien deposits are believed to be the best, with grade of ore around 3 per cent molybdenum in veins of 6 to 7 centimeters in thickness and 30 meters long. Production in Fukien was, at one time, large. In 1923, 15.2 tons of molybdenum ore was recorded as export. The recent production in Liaoning is not known and that in Kwangtung has been small.

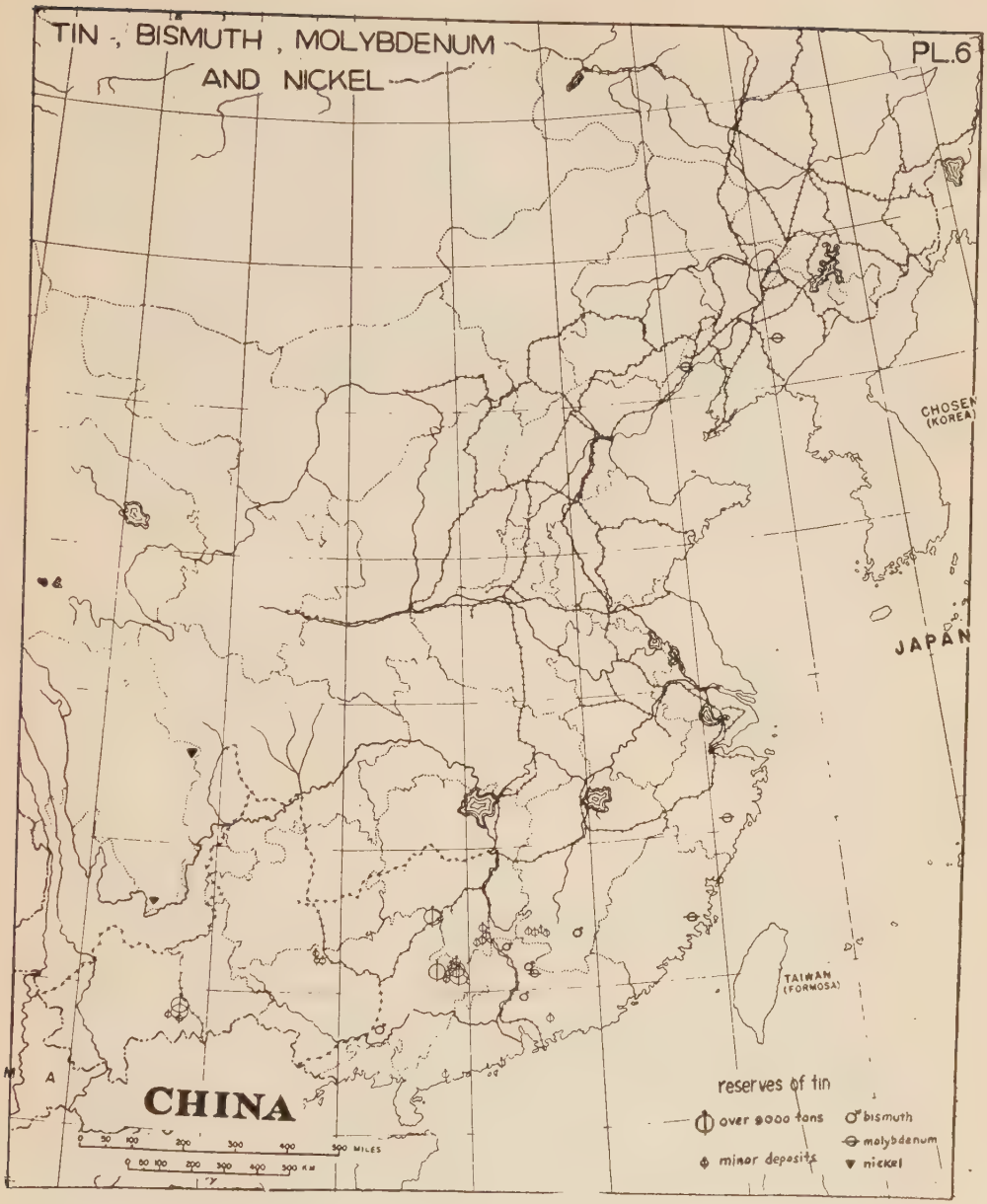
TABLE 23.

PRODUCTION OF MOLYBDENUM IN CHINA.*

(45% Mo, concentrate, in metric tons.)

	Kwangtung	Fukien	Liaoning
1923		15.2	
1930	5	None	—
1931	—	None	—
1932	.7	None	—
1933	.6	None	—
1934	.5	None	—

* Hou, no. 5, 1935.



Nickel.

Nickel deposits of China are so far only known in Sikang province (Fig. 6). The ore occurs as nickeliferous pyrrhotite in peridotite dikes. The reserves of the deposit have been estimated at 320,000 tons ore of .5 per cent nickel content.

Tin.

Geographical Distribution.—The tin deposits of China (Fig. 6) occur in the mountainous region of Nanling Range where tungsten deposits are found, and in hilly countries north and west of it. The area covered spreads from southern Yunnan northeasterly to southern Kiangsi and from northern Kwangsi southeasterly to Hainan Island. But the important tin belt lies in the northern part of this area in alignment with the trend of the Nanling Range. It is richer in the western section, mainly in Kwangsi and Yunnan, than in the eastern section.

Yunnan deposits, the richest in China, contain more than 80 per cent of the country's tin reserves in an area of 600 sq. km. The remaining 20 per cent of China's reserves, which are tentatively put at 1,837,370 tons of metal, is distributed in northern and eastern Kwangsi, southern Hunan, southern Kiangsi and the coastal regions of Kwangtung. Yunnan also has the largest concentration of primary tin ore, that is, ores occurring in situ; while Kwangsi possesses the important placers. Only small placers have hitherto been found in Kwangtung. Both primary ores and placers occur in Hunan and Kiangsi.

TABLE 24.

ESTIMATED TIN RESERVES IN CHINA.

(Metric tons.)

Province	Tonnage of Metal
Yunnan	1,500,000
Kwangsi	100,000
Kwangtung	5,000
Kiangsi	263,370
Hunan	5,000*
Total	1,873,370

* Estimated.

Ore Deposits.—Tin deposits of China fall into three types: primary replacement and fissure-filling deposits in limestone near a granite intrusion, replacement deposits in greisenized granitic rocks, and secondary placer deposits.

Occurrence in limestone is by far the most important type represented by ores in Yunnan. In this type, the ore occurs as limited sausage-shaped bodies following a more or less well-defined strike along the bedding planes of the country rock and as pipe-like or irregular deposits. The sausage-shaped deposits, in general, have a thickness ranging from 1–6 to 10 meters and a length of 10 to 15 meters. The dimensions of the irregular ore bodies are much larger. The vertical extent is not definitely known, but ores at depths of 500 to 850 meters have been mined. The ore mineral is cassiterite associated with limonite and hematite, and in places small amounts of arsenic, copper, lead and zinc are found. The average grade of ore ranges from 2.4 to 5 per cent tin. The replacement deposits in granite assume the form of veins which are generally associated with thick zones of greisen in the upper portion of the granite cupolas. The veins contain cassiterite, as well as wolframite, and are found mostly in the tungsten region in southern Kiangsi and southern Hunan.

Workable cassiterite is also present in the greisen itself. The size of the vein is small. The tin placer deposits in China are more productive than the veins in granite and are more widespread. The placer tin, mostly weathered from granite, has accumulated in benches and narrow plains. Small, rich deposits are also found in sinkholes and fissures in limestones. In Kiangsi, where the most productive placers occur, the placer beds have a thickness of .3 to 30 meters, beds of 2 to 3 meters being common. The tenor of the placers varies from 300 to 2,560 grams per cubic meter.

Mining and Production.—Tin mining in China has been active for almost two hundred and fifty years (1697–1945), and Yunnan mines at times have given employment to more than 100,000 men. Lode mining is entirely by crude methods, but placer mines in Kwangsi are mostly operated mechanically. Washing gives concentrates with 70 per cent tin. The concentrates are

TABLE 25.

TIN PRODUCTION IN CHINA.

(Metric tons.)

	Yunnan[a]	Kwangsi[a]	Hunan[b]	Kwangtung[b]	Kiangsi[b]	Total	
							[c]
1934	6,808	669	90	140	600	8,307	8,004
1935	8,865	1,146	—	—	—	10,011	—
1936	9,796	2,050	—	—	—	11,846	10,357
1937	9,187	3,098	—	—	—	12,285	11,759
1938	10,732	3,519	—	—	—	14,251	11,127
1939	10,156	2,867	—	—	—	13,023	—
1940	8,240	2,446	—	—	—	10,686	16,497
1941	6,400	2,291	—	—	—	8,691	6,994
1942	5,653	1,616	—	—	—	7,269	4,037
1943	2,113 — (Jan.–Nov.)	515	—	—	—	—	3,567 — (Jan.–Nov.)

[a] Morris, J. M., Field report on Chinese tungsten and tin mining industries, Foreign Econ. Adm., pt. 3, 1943.

[b] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 5, 1935.

[c] Morris, J. M., op. cit. (Figures are too low for production probably represent export.)

— Data not available.

smelted in blast furnaces and molded into tin bars having 99.8 per cent to 99.98 per cent Sn.

From 1934 to 1943, China produced annually 7,000 to 14,250 tons of tin. China normally supplies about 7 per cent of world consumption and one-third of it goes to the United States. Of China's production, the lode ore forms the bulk, and less than one-third comes from placers. Yunnan is the chief producing region followed by Kwangsi, Kiangsi, Kwangtung and Hunan in order of importance. Yunnan alone produces normally more than 85 per cent of the total output.

Information on China's tin consumption at the present time is lacking. Before the war, it was estimated annual consumption was about 10,000 tons of tin. Although China has a wide-spread handcraft industry in making tin foils, her output of tin was largely exported as bars in exchange for finished products, such as tin plates and tin cans.

Future Prospect of Supply.—Yunnan is by far the foremost tin-mining province and is capable of maintaining its position for years to come. There are many million tons of tin placers in Yunnan, which, due to the fineness of the cassiterite, have not been worked in the past. Observation has invariably disclosed increasing possibilities of mining operations in that area and discovery of new ore bodies in virgin ground is definitely to be expected. In Kwangsi and Kwangtung, many of the placer deposits have not been seriously prospected, and tailings in many mining districts would pay to be reworked when better extraction and smelting methods are introduced.

China occupies fifth place in the world's tin production, preceded only by Federated Malay States, Dutch Indies, Bolivia, and Belgian Congo. With the increased demand for tin and depletion of the Bolivian reserves, China will have every possibility of occupying an even more important place in the post-war era.

Antimony.

Geographical Distribution.—Antimony ores of China, the world's principal sources of antimony, lie mainly in southwestern China, though deposits are also found on the border of Anhui and Chekiang in southeastern China (Fig. 7). In southwestern China, the commercially most important deposits are in Hunan, Kueichow and Kwangsi, while only a few small deposits are productive in Kwangtung and Yunnan.

Antimony ores occur roughly in three parallel belts running approximately east and west. The northern belt, the richest, extends from the northeastern part of Kueichow eastward through northern Hunan to as far as southern Anhui. The central belt is confined to the mountainous country of the so-called Nanling Range at the borders of Kueichow-Kwangsi and Hunan-Kwangtung. The southern belt, the smallest of all, forms a line from southern Yunnan to central Kwangsi. These belts follow the belts of acid igneous intrusions, in a general way.

In Hunan province, antimony ore occurs principally in three regions: the north-central part of the province southwest of Tungting Lake, the south-central part near the Hunan-Kwangsi railroad and the southernmost part close to the border of Kwangtung province. The principal resources are concentrated in the north-central part. Except for one occurrence near the border of Kwangtung, only small deposits are found in the south-central and southern parts of the province. Hunan possesses the richest deposits constituting 88 per cent of China's antimony reserves which have been estimated at 4,223,040 metric tons of metal.

Next to Hunan in importance is Kueichow where antimony ores are found in the eastern part of the province. Among many occurrences only two large deposits are known, each having a reserve of over 40,000 metric tons of metal. Kwangsi next to Kueichow has one large deposit in the northern part and many small ones in the southern part of the province. Deposits in Kwangtung, Yunnan, Anhui and Chekiang are small in extent, so far as present knowledge goes, though Anhui deposits are known as excellent in quality.

The reserves of the antimony for Kueichow, Kwangsi, Kwangtung, Yunnan and Anhui together are given at 500,000 tons of metal.

TABLE 26.

ESTIMATED RESERVES OF ANTIMONY IN CHINA.*

Province	Tonnage of Metal
Hunan	3,723,040
Kueichow, Kwangsi, Kwangtung, Yunnan and Anhui	500,000
Total	4,223,040

* Hou, no. 5, p. 236, 1935.

Ore Deposits.—All the important antimony deposits in China appear as lode ores; only at one location in Kwangsi are lumps and concretions of antimony ore found in red clay. The lode ores are furnished by the siliceous antimony lodes formed by fissure filling in sandstones and slates, and arsenic-lead-antimony lodes of replacement type in limestones. The former is the predominate type of ore in China.

The country rock of the antimony lodes is sedimentary as a rule, but it differs both in age and lithology. The Hunan deposits are definitely known to occur in Upper Devonian quartzitic sandstone and limestones, and in Kueichow deposits have been found in metamorphosed pre-Cambrian slate. Except in Kwangsi where ores are found in younger Tertiary red clay, the occurrences in the rest of the antimony provinces are in different formations of Paleozoic age. Yunnan and Chekiang and possibly Anhui ores occur in limestone, but ores are found only in sandstone in Kwangtung. Practically all the antimony lodes are in association with acid intrusive rocks; the commonest type is quartz diorite, which is either Late Jurassic or Early Tertiary in age.

As already noted above, China's antimony deposits may be differentiated into two principal types: fissure-filling and replacement deposits. The first may also be called stibnite-cinnabar lodes and the second, stibnite-galena lodes. The stibnite-cinnabar lodes occur as veins and stockworks in siliceous rocks in shear zones. The primary ore mineral is exclusively stibnite as acicular crystals or as pure crystalline masses. Pyrite impregnations and patches of cinnabar occur only in the cement of the brecciated siliceous rocks and are not abundant. Gold has, so far, not been found. Quartz, often in beautiful druses of clear prismatic crystals, is the only gangue mineral. It appears from the information available that the ores of this type are of very high grade. All deposits occur along lines of fracturing; large stockworks are produced in shear zones. There is no evidence that the nature of the country rock has affected the mineralogy of the lodes, but the physical character of the enclosing rock has greatly influenced the structure of the deposits. Larger and less irregular veins are likely to be found in slate. In Hunan, stockworks predominate. The individual bodies of nearly pure stibnite may be as large as 5 by 3.5 by .75 meters. In Kueichow, veins range in widths from .1 up to 4 meters with an average width of .4 meter. The vertical extent of the ore bodies is not definitely known. In Kwangtung a vein extending 70 meters below the surface has been found. The grade as mined in Hunan ranges from

19 to 25 per cent while the average tenor of the deposit is 6 to 9 per cent stibnite.

The stibnite-galena deposits are less important in China. They appear to be replacements of limestones. Besides galena, arsenopyrite and pyrite are also present. The veins in limestone are more regular than the stibnite-cinnabar lodes. One vein found in Kwangsi has a width of 1 meter. The grade is generally high ranging from 20 to 57 per cent stibnite.

All of the deposits show oxidation near the surface and cervantite is found as white or yellowish porous masses, or as beautiful pseudomorphes after stibnite; faceted crystals have not been observed.

Mining and Production.—Hunan antimony mining is said to have been worked in the 16–17th century. The output long remained very insignificant but began to increase at the beginning of this century and soon surpassed the production of any other country in the world. At present, antimony mining is active in every province where it is available, except Anhui and Chekiang. Mining was carried on by crude methods in most deposits. Systematic mining was started in Hunan in 1927 when vertical shafts and mining levels were developed. Ores are smelted mostly at the point of production. Ore as sent to furnaces is hand picked and cobbed to a grade of 40 to 60 per cent. Smelting at the principal mines is by Herrenschmidt furnaces. The antimony is generally prepared in three forms: the regulars of 99 per cent Sb, crude antimony of 70 per cent metal content and the antimony oxide of 50 per cent Sb.

Before 1934, Hunan output represented 99 per cent of the total production in China but rapid development in Kueichow and Kwangsi has been shown in recent years. China produced annually from 1929 to 1937 about 14,000 to 20,000 tons of antimony metal, equivalent to 37 to 76 per cent of world's total. More than 80 per cent of China's total production was exported to Great Britain, Japan, the United States and Germany in the order of magnitude.

TABLE 27.

ANTIMONY PRODUCTION IN CHINA.

(Metric tons.)

	Hunan[a]	Kueichow[b]	Kwangsi[b]	Kwangtung[a]	Yunnan[b]	Total[c]
1929	20,233	—	—	—	—	20,303
1930	17,963	—	—	—	—	17,992
1931	14,428	—	—	—	—	(13,434)
1932	14,030	—	45	30	—	14,105
1933	14,156	—	—	10	—	14,166
1934	16,326	—	—	—	—	16,326
1935	—	—	1,000	—	—	18,501
1936	—	—	6,000	—	—	17,038
1937	—	—	6,300	—	—	15,146
1938	—	138	6,500	—	15	—
1939	—	30	11,500	—	15	—

[a] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 5, 1935.
[b] Chin, Y. H., Spec. Report, Geol. Surv. China, no. 6, 1941.
[c] Mineral Industry, 1941.

TABLE 28.

ANTIMONY OUTPUT IN CHINA.
(Metric tons.)

Year	China's Output[2]	World's Output[2]	Percentage Produced in China
1929	20,303[1]	33,200	61
1930	17,992[1]	25,300	71
1931	14,428[1]	19,900	72
1932	14,105[1]	18,500	76
1933	14,166[1]	21,100	67
1934	16,326[1]	23,200	70
1935	18,501	32,000	58
1936	17,038	38,800	43
1937	15,146	42,600	37

[1] Hou, T. F., Spec. Rept. Geol. Surv. China, 1935.
[2] Mineral Industry, 1941.

Future Prospect of Supply.—Before 1937 China's antimony production was very steady, while the world's production was increasing due to increased output from other countries, chiefly Mexico and Bolivia. Since 1938, Chinese antimony production has greatly declined with the interruption of mining by the chief producers in Hunan. However, the available resources are large and

TABLE 29.

DISTRIBUTION OF ANTIMONY EXPORTS FROM CHINA.
(Long tons.)

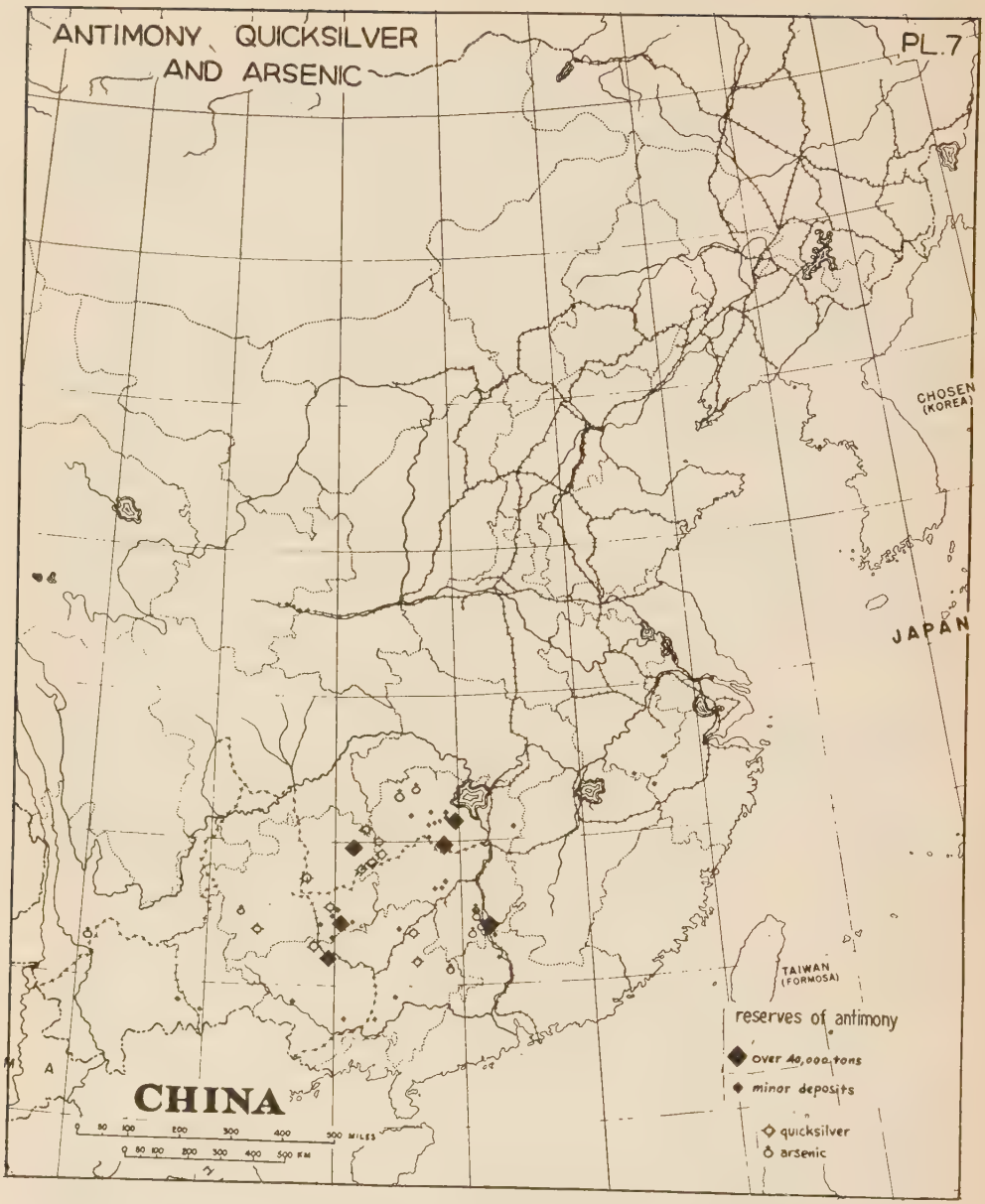
Country	1932[1]	1933[1]	1934[1]	1935[1]	1936[1]	1937[1]	1938[1]	1939[1]
United States	2,239	2,984	2,598	3,324	2,420	1,614	—	—
Belgium		570	530	746	661	453	10	—
France	685	343	716	350	626	107	—	—
Germany	1,080	1,324	2,360	2,527	2,018	1,081	20	—
Gr. Britain	4,820	4,057	4,778	5,936	5,135	4,344	—	—
Italy	—	410	105	619	568	434	—	—
Netherlands	—	930	1,446	707	706	494	—	—
Japan	1,632	2,457	2,451	2,977	3,527	2,226	384	—
Others	2,502	639	950	1,316	6,652	4,635	7,915	6,760
Total	12,933[2]	13,713	15,934	18,501	17,312	15,388	7,983	6,760

[1] Mineral Industry, 1941.
[2] Hou, T. F., Spec. Rept. no. 5, 1935 (in metric tons).

the important deposits are capable of greater yield than in pre-war years. With low cost of production, China's leadership in the antimony market may require stabilized production by using the most efficient methods and regulating exports. There is no danger of exhaustion in the near future.

Mercury.

Geographical Distribution.—The mercury ore of China (Fig. 7) is closely associated with antimony deposits. The principal occurrences are in Kueichow province and the adjacent parts of the neighboring provinces of Szechuan,



Hunan and Kwangsi. Many deposits are scattered in this broad belt, about 500 kilometers across from the southeastern Szechuan to the northern Kwangsi, and trending NE to SW from western Hunan to western Kueichow. However, the most important deposits are located on the Kueichow-Hunan border where at least six deposits are productive, of which the five major ones are Houtzeiping in Fenghuang, Talungla and Anwuping in Tungjen,

Wanshanchang in Shengchi and Tienjuanping in Yuping. Deposits within Kwangsi and Szechuan are small. None of them has yet proved to be of great economic importance.

Ore Deposits.—The mercury ores, like antimony ores in China, show on the whole a close association with igneous rocks and zones of fissuring. They appear as a low-temperature phase of the mineralization responsible for the antimony deposits. As a rule they are found farther away from the igneous bodies and do not extend to great depth. Mercury deposits occur as irregular veins in stockworks in brecciated layers of limestone and shale ranging in age from Upper Ordovician to Permian. Most of the occurrences are confined to the anticlines, where fracturing favors the infiltration of solution, and to vertical fissure lines independent of the general folding, but well protected from denudation. The age of mineralization is probably Late Mesozoic to Early Tertiary. The mercury mineral is almost exclusively cinnabar which occurs as small crystals or aggregates of crystals disseminated in the beds of sedi-

TABLE 30.

MERCURY PRODUCTION IN CHINA.

(Metric tons.)

	Kueichow	Hunan	Kwangsi	Total
1929[a]	10.3	13.5	—	24.8
1930[a]	10.5	30	—	40.5
1931[a]	.5	22	—	22.5
1932[a]	.5	—	—	.5
1933[a]	.5	—	—	.4
1934[a]	.54	—	—	.54
1935	—	—	—	—
1936[b]	4.9	—	.3	—
1937[b]	15.6	—	.3	—
1938[b]	18.1	—	.3	—
1939[b]	14	—	.3	—

[a] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 4, 1932; no. 5, 1935.
[b] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941.

mentary rock. Onofrite, native mercury and antimonial cinnabar are rare. Stibnite, calcite, quartz, bitumen and pyrite are associated minerals. In the most productive mine of Wanshanchang, three ore-bearing horizons have been found, but in other places, only one horizon with a thickness of 1.5 to 6 meters and a length of 100 to 1,000 meters has been recognized. No ore mined consists of pure cinnabar. The richest ore shoots that have been found in the immediate vicinity of the tectonic lines, yielded about 4.4 per cent mercury. The average yield of the ores in China during the past was about 1 per cent.

Mining and Production.—The use of vermilion ink and paint was known in China several centuries B.C. Mercury mining was recorded in the 14th century. The most prosperous period of mercury mining seems to have been in the seventies, since which time the output has been gradually decreasing. Mining in the northern part of the Kueichow province had a more steady growth than that in the south, and the Tungjen prefecture now has become the chief center of production.

Mining methods are primitive. The ore is sorted in the mine and concentrated by cobbing and crushing. Two different metallurgical methods have been used in China, the decomposition of sulphide in closed iron vessels and oxidation of sulphur by air. It has been estimated that the iron-retort process involved a loss of 30–40 per cent of the mercury in the ore.

The output of mercury in China has fluctuated considerably in the past. In recent years the output of vermilion (cinnabar) has reduced greatly owing to replacement in the foreign market by cheap substitutes. The bulk of the output is now transformed into metal, because mechanical treatment alone is no longer sufficient for economical recovery from lean ores.

The individual mercury deposits in China are not particularly large and the ore is decidedly inferior to that obtained in Spain and Italy.

Arsenic.

Arsenic is mainly produced in China as a by-product of tin mining, and subordinately from deposits of realgar and orpiment. In Hunan and Kwangsi, the arsenopyrite ores recovered from tin-arsenic veins are distilled locally to arsenic oxide and sold chiefly for production of insecticides. The product furnished about two-thirds of the arsenic consumed in China. The realgar and orpiment deposits found in northern Hunan, western Kueichow and western Yunnan were mined for export exclusively to Burma and India (Fig. 7).

The arsenopyrite is chiefly derived from pipe-like ore-bodies containing both cassiterite and arsenopyrite. Arsenopyrite, the principal mineral near the surface, is associated with increasing amounts of cassiterite in depth. Realgar and orpiment deposits occur in the form of lenses in limestone and sandstone. The deposits in Yunnan occur as bands, 2–3.3 meters long and .04 to .15 meters thick, along the joint and bedding planes in sandstones. The important associated mineral is pyrite.

Mining was conducted in a very crude way, the ore being sorted by hand. China's arsenic production has declined greatly since 1929. The following table shows the records available from 1929 to 1938.

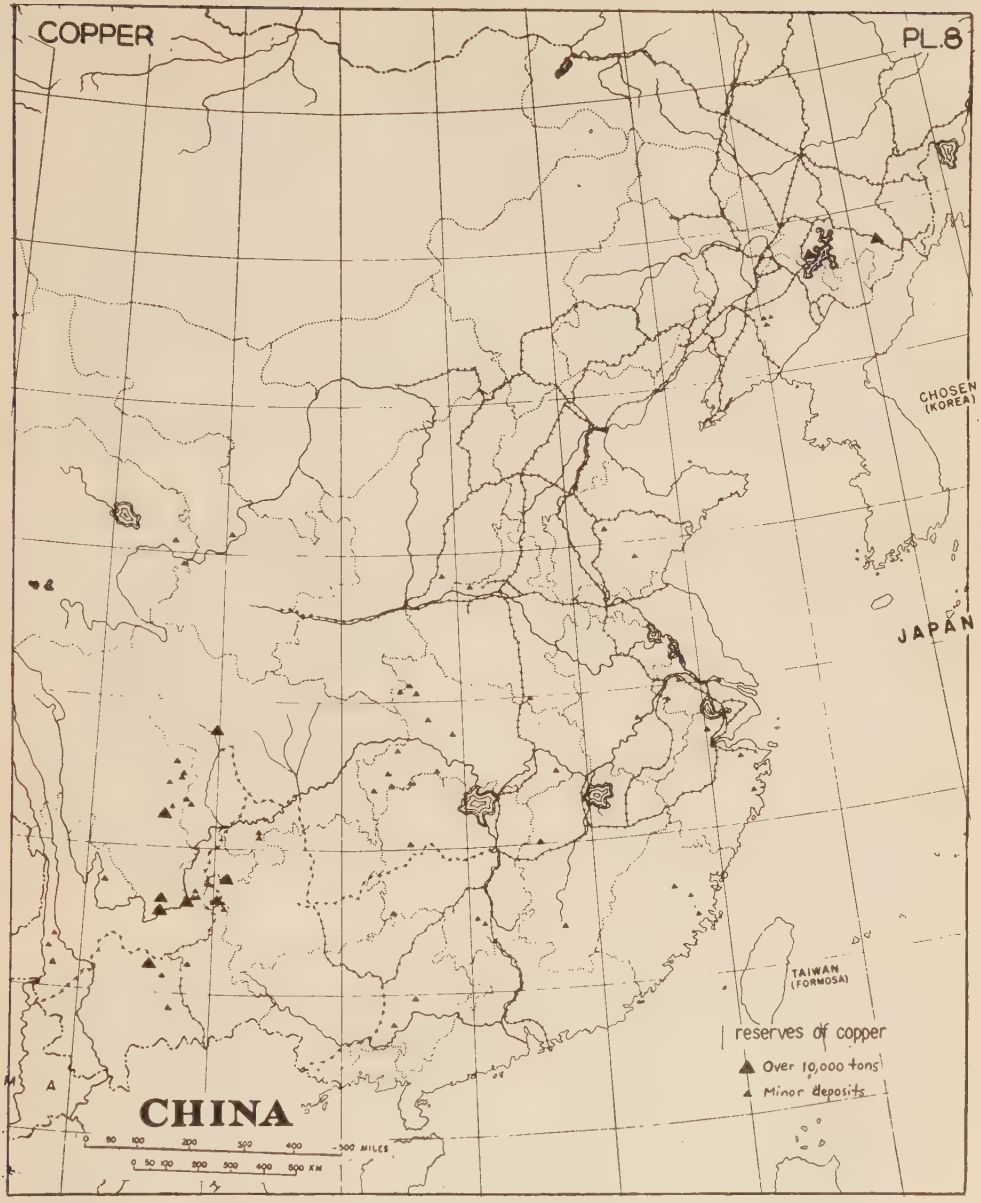
TABLE 31.

ARSENIC PRODUCTION IN CHINA.

(Realgar and Oxide, in metric tons.)

Year	Yunnan	Hunan	Kwangsi	Total
1929[a]	471	1,878	—	2,349
1930[a]	559	440	—	999
1931[a]	443	822	—	1,300
1932[a]	459	954	14	1,427
1933[a]	392	750	17	1,159
1934[a]	371	820	15	1,206
1935[b]	75	—	—	—
1936[b]	32	—	—	—
1937	—	—	—	—
1938[b]	295	—	—	—

[a] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 4, 1932.
[b] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941.



Copper.

Copper is widely distributed in China (Fig. 8) occurring in almost every province. But the deposits of importance are limited to five regions: Southern Manchuria, the southeastern coastal region, the Yangtze Valley, the southwestern region and Sinkiang province.

Genetically, the copper deposits of China are classified into six types; pneumatolytic, contact-metamorphic, hydrothermal, deposits in basic lava, and sedimentary. The pneumatolytic type of ore is important in the southwestern region where copper has been mined since 1695. The ore occurs either in metamophosed sandstone and shale, or in Carboniferous limestone. Chalcopyrite, the chief primary mineral, is associated with pyrite, sphalerite, tetrahedrite and galena. The Tungchuan deposit in Yunnan shows prominent oxidized zone which extends to depths of 15 to 25 meters. In this zone rich deposits of bornite and chalcocite have been mined. Contact-metamorphic deposits are rather important in southern Manchuria and Yangtze Valley. They occur mostly at the contact of dioritic rocks and limestones and subordinately at the contact of granite or prophyries and sandstones. The richest deposit of this type so far known is the Tienpaoshan deposit of Kirin. The ore vein is composed of chalcopyrite, pyrite, argentite, sphalerite and galena in a gangue of calcite and other contact minerals. The amounts of lead and

TABLE 32.

Estimated Copper Reserves in China.

(Metric tons.)

Province	Tonnage of Ore	Cu Content	Tonnage of Metal
Kirin[1]	3,000,000	1.8%	54,000
	53,000	16.9%	500
Kueichow		2.5–5%	638,480
Yunnan		12 –16%	568,370
Szechuan		1.5–4.1%	22,520
Sikang		2.6–18%	809,480
		Total	2,093,350

[1] Murayama, Kazutura, Report on the geology and ore deposit of the Tienpaoshan mine, Manchuria: Ryojun College Eng. Mem., vol. 13, pp. 11–20, 1940; Utino, T., and Okada, S., Geology and ore deposits of the Shih-tsu-tzu copper mine, Panshih Prefecture, Chilin Province, Geol. Inst. Manchuria, Bull. no. 102, pp. 17–26, 1941.

zinc present are adequate for recovery as by-products. The hypothermal type of deposit has a wider geographical range than the above two types. It has been found in Szechuan in the west, Shantung in the north and Fukien in the south. The deposits occur as pyrrhotite-chalcopyrite veins and bornite-chalcopyrite veins in metamorphosed rocks. The mesothermal type of deposit seems to have been found in all the five regions. It occurs as veins, pockets or disseminations in limestone and metamorphosed rocks. The ore minerals are chalcopyrite, pyrite, sphalerite, tennantite and enargite in a gangue of quartz and calcite. Copper deposits in the basic lavas are found only in southwestern Szechuan, eastern Yunnan and western Kueichow. The ore occurs as veins in fissures and as fillings of amygdaloidal vesicles. Chalcopyrite predominates but native copper has also been found. The deposits of this type are generally small in extent and usually poor in quality. The sedimentary type of deposit has been found in Permian and Triassic formations in southwestern Szechuan, eastern Yunnan and eastern Kueichow. The ore appears

TABLE 33.

COPPER PRODUCTION IN CHINA.
(Metric tons.)

	Yunnan[a]	Szechuan[a]	Kueichow[a]	Sikang[a]	Liaoning[b]	Kirin[b]	Total
1931	415	25	23	—	—	—	463
1932	520	20	—	—	—	—	520
1933	436	10	—	—	—	—	446
1934	485	—	40	—	—	—	525
1935	345	—	—	—	—	—	345
1936	269	—	—	15	200	500	984
1937	352	—	—	4	200	500	1,056
1938	339	—	—	7	200	500	1,046
1939	588	—	—	140	200	500	1,428

[a] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 5, 1935.
[a] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 5, 1935. Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941.
[b] Estimates.

as nodules or disseminations in shale and sandstone. The chief copper-bearing mineral in the nodules is bornite which has replaced chalcopyrite with pyrite inclusions. Both chalcopyrite and chalcocite are found in disseminated beds. Although the ore-bearing beds are widely distributed, deposits of this type in China are of less importance than the others because of the rather low grade of the ore.

Many copper deposits in China have not yet been investigated but all of those so far known have produced copper at one time or another. The reserves for the most important deposits known at present are given in the following table. It is believed that future exploratory work may reveal other bodies in old workings and new deposits in virgin ground.

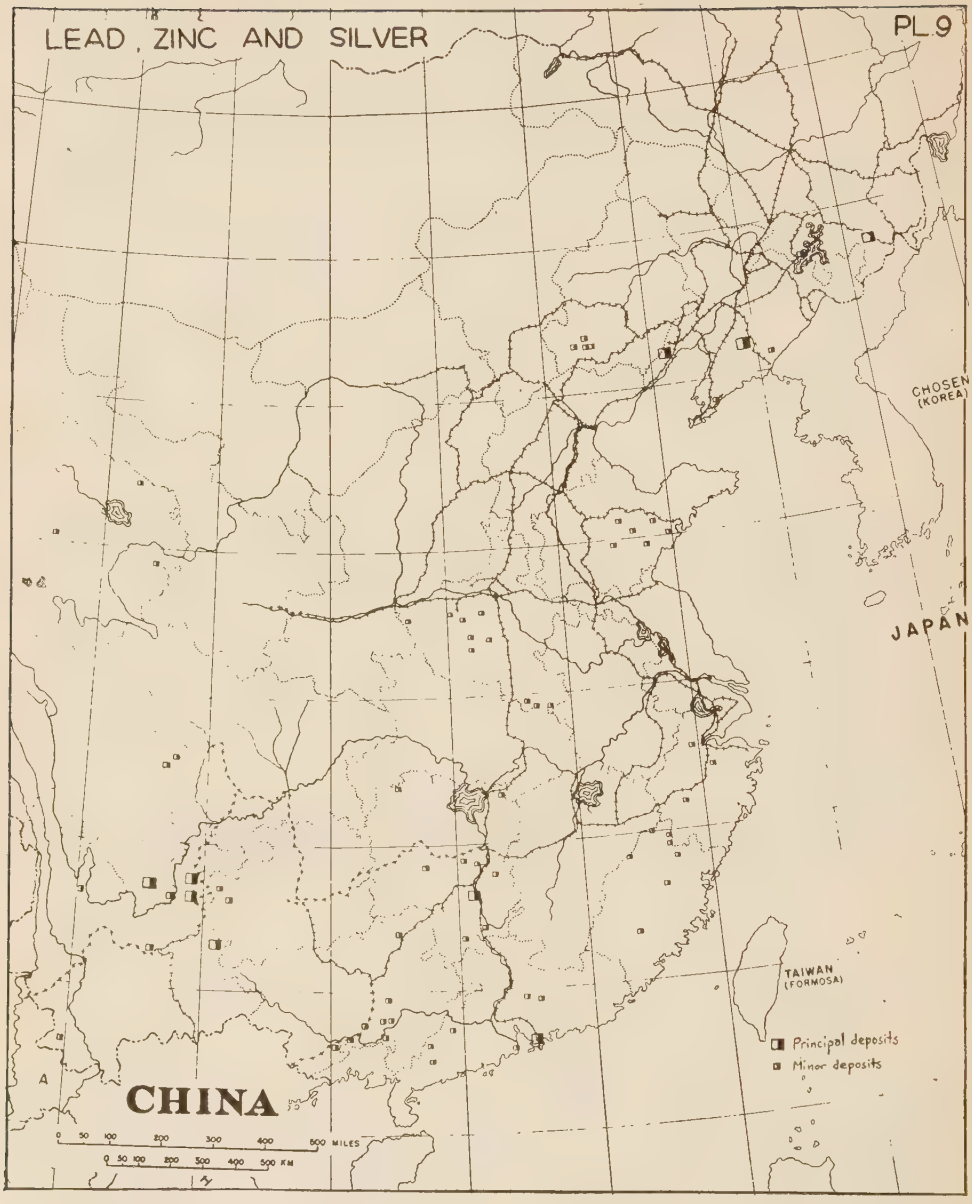
Yunnan has been the chief center of copper production in China. Copper is said to have been smelted in that province for at least a thousand years.

TABLE 34.

ESTIMATED RESERVES OF LEAD IN CHINA.
(Metric tons.)

Province	Tonnage of Ore	Pb Content	Tonnage of Metal
Liaoning[1]	2,100,000	6.9%	144,900
	2,000,000	about 10%	200,000
Kirin[2]	3,000,000	5%	150,000
Hunan		20%	50,000[3]
Kwangtung		10%	10,000[3]
Yunnan		20–30%	50,000[3]
Sikang		18%	1,000[3]
Kueichow		20%	20,000[3]
			625,900

[1] Ogura, T., Silver, lead and zinc deposits of Manchuria, Ryojun College Eng. Mem., vol. 12, pp. 205–242, 1939.
[2] Murayama, Kazutura, Report on the geology and ore deposit of Tienpaoshan mine, Manchuria, Ryojun College Eng. Mem., vol. 13, no. 1, pp. 11–20, 1940.
[3] Estimates.



All copper mines were operated by hand methods. The following shows the production of copper in China from 1931 to 1939.

Lead, Zinc and Silver.

Lead, zinc and silver deposits are found in China in many provinces, and are as widely distributed as the copper deposits (Fig. 9). The ore occurs

generally as a replacement in limestone and as hydrothermal deposits in quartzite and sandstone near the granite intrusions. In Hunan, the ore consists of galena mixed with zinc-blende; while in Manchuria ore occurs in genetic association with copper minerals and in Sikang zinc and lead carbonates predominate.

TABLE 35.

ESTIMATED RESERVES OF ZINC IN CHINA.

(Metric tons.)

Province	Tonnage of Ore	Zn Content	Tonnage of Metal
Liaoning[1]	2,100,000	8.8%	184,800
Kirin[2]	3,000,000	6%	180,000
Hunan		30%	70,000[3]
Yunnan		40%	20,000[3]
Sikang		20%	40,000
			494,800

[1] Ogura, T., Silver, lead and zinc deposits of Manchuria, Ryojun College Eng. Mem., vol. 12, pp. 205–242, 1939.

[2] Murayama, Kazutura, Report on the geology and ore deposit of Tienpaoshan mine, Manchuria, Ryojun College Eng. Mem., vol. 13, no. 1, pp. 11–20, 1940.

[3] Estimates.

The best deposits so far worked is the Shuikoushan deposit in Hunan, whose ore contains 20 per cent galena and 30 per cent sphalerite with considerable amounts of silver. Second in importance are the deposits in northern Yunnan and southern Sikang. Southern Manchurian ores have only become important in recent years.

TABLE 36.

LEAD PRODUCTION IN CHINA.

(Metric tons.)

	Yunnan	Sikang	Hunan[a]	Kwangtung	Kirin	Liaoning
1929	600[b]	—	5,933	—	—	—
1930	600[b]	—	5,274	—	—	—
1931	600[b]	—	3,738	—	—	—
1932	600[b]	20	—	—	—	—
1933	600[b]	20	—	—	—	—
1934	600[b]	20	—	—	—	—
1935	614[c]	—	—	—	—	—
1936	584[c]	—	—	—	—	—
1937	584[c]	—	—	—	—	—
1938	504[c]	—	—	2,992[b]	—	—
1939	897[c]	—	—	—	—	—
1940	—	—	—	—	4,500[b]	—
1941	—	—	—	—	—	—
1942	—	—	—	—	—	13,000[b]

[a] Export, Liu, C. P., and others, Geol. Surv. Hunan, Bull. 4, 1932.

[b] Estimates.

[c] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941.

TABLE 37.

ZINC PRODUCTION IN CHINA.

(Metric tons.)

	Yunnan	Sikang	Hunan[a]	Kirin	Liaoning	Kwangsi
1929	300[b]	—	21,568	—	—	—
1930	300[b]	—	7,467	—	—	—
1931	300[b]	—	19,013	—	—	—
1932	300[b]	300[c]	—	—	—	335
1933	300[b]	300[c]	—	—	—	62
1934	300[b]	300[c]	—	—	—	—
1935[c]	249	50	—	—	—	—
1936[c]	221	50	—	—	—	—
1937[c]	277	50	—	—	—	—
1938[c]	277	40	—	—	—	—
1939[c]	243	40	—	—	—	—
1940	—	—	—	5,000[b]	—	—
1941	—	—	—	—	—	—
1942	—	—	—	—	20,000[b]	—

[a] Export, Liu, C. P., and others, Geol. Surv. Hunan, Bull. 14, 1932.
[b] Estimate.
[c] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941.

Gold.

Gold in China is mostly obtained from placers. Gold-bearing quartz veins of North China, with the exception of the Heilungkiang, Shantung, Hunan and Sinkiang deposits, give little promise (Fig 10). Before the war, Heilungkiang was the leading producer of the country. The total production of gold

TABLE 38.

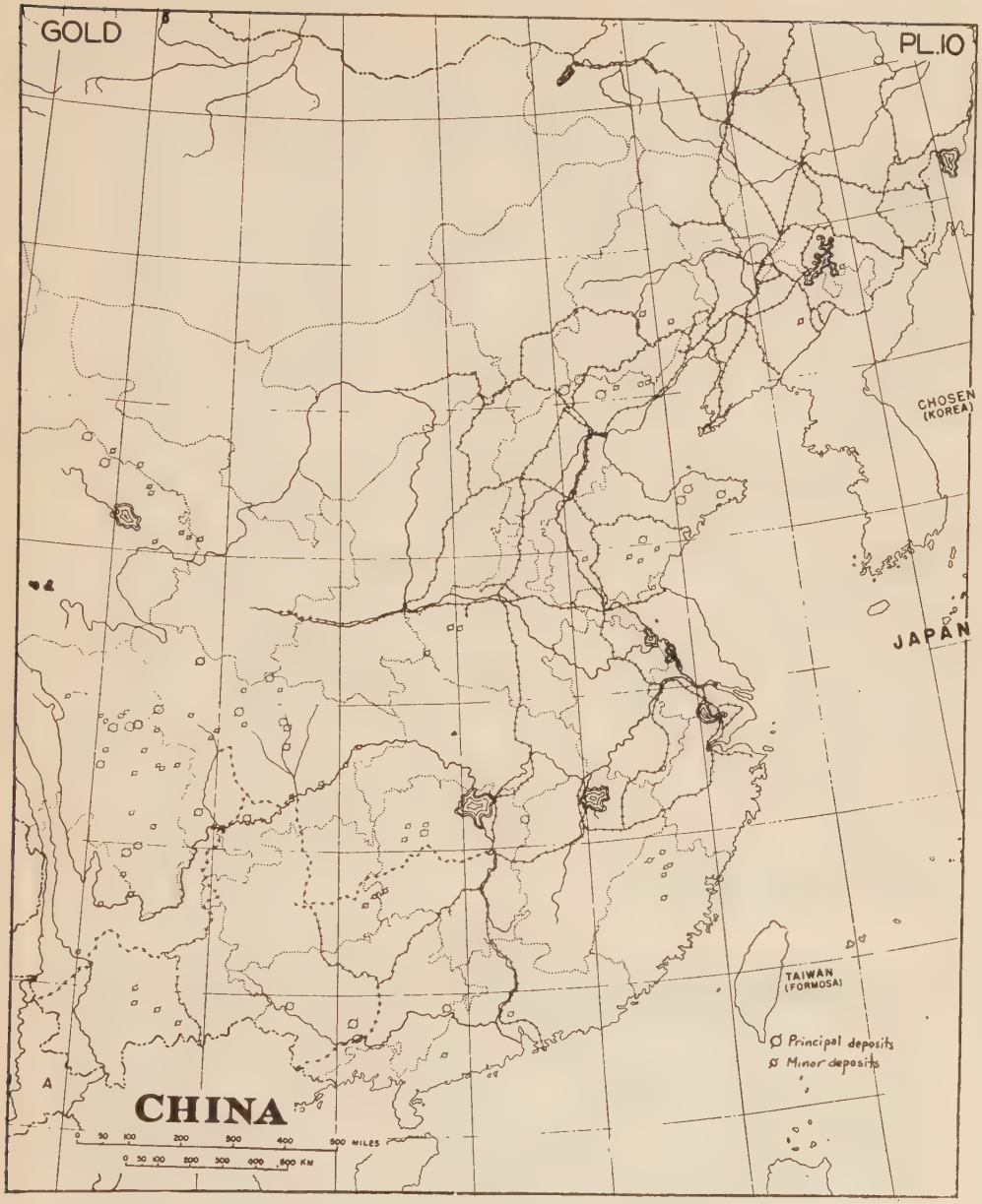
SILVER PRODUCTION IN CHINA.

(Troy ounces.)

	Yunnan[a]	Hunan[b]	Kwangtung[c]
1930	—	119,594	—
1932	—	105,000	—
1933	—	200,585	—
1934	—	121,504	—
1935	—	—	—
1936	—	—	—
1937	—	—	—
1938	—	—	111,070
1939	2,090	—	—

[a] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941.
[b] Liu, C. P., and others, Geol. Surv. Hunan, Bull. 14, 1932.
[c] Mine Magazine (Colorado School of Mines), vol. 29, 1939.

in China then ranged from 140,000 to 167,000 troy ounces. Under the impetus of war, the production of placer gold in the southwestern region has been greatly increased. The total production in 1939 in this region including Szechuan, Sikang, Kwangsi, Kueichow and Yunnan was over 84,000 troy ounces against the peak pre-war production of 52,000 troy ounces.



Although at some of the lode mines modern methods have been used for mining and extraction, almost all the placer deposits have been operated by crude methods without employing any mechanical equipment. Many deposits in Manchuria and the southwestern region can be worked by dredging. Serious development of the gold-mining industry in these most favorable places

TABLE 39A.

GOLD PRODUCTION IN CHINA.

(Troy ounces.)

	1931[a]	1932[a]	1933[a]	1934[a]
Heilungkiant	52,461	8,364	15,148	39,000
Kirin	28,180	—	3,145	3,840
Liaoning	2,560	—	256	640
Jehol	650	—	4,577	6,500
Hopeh	2,560	32,192	13,056	14,362
Shantung	—	390	390	1,950
Hunan	2,600		140	268
Szechuan, Sikang	20,605	39,000	52,000	39,000
Kansu, Tsinghai	19,500	19,500	19,500	19,500
Sinkiang	36,800	38,600	36,800	38,800
Honan, Kwangtung	1,040	1,300	1,300	1,300
Total	166,956	137,546	146,312	162,160

[a] Hou, T. F., Spec. Rept. Geol. Surv. China, no. 5, 1935.

TABLE 39B.

GOLD PRODUCTION IN CHINA.

(Troy ounces.)

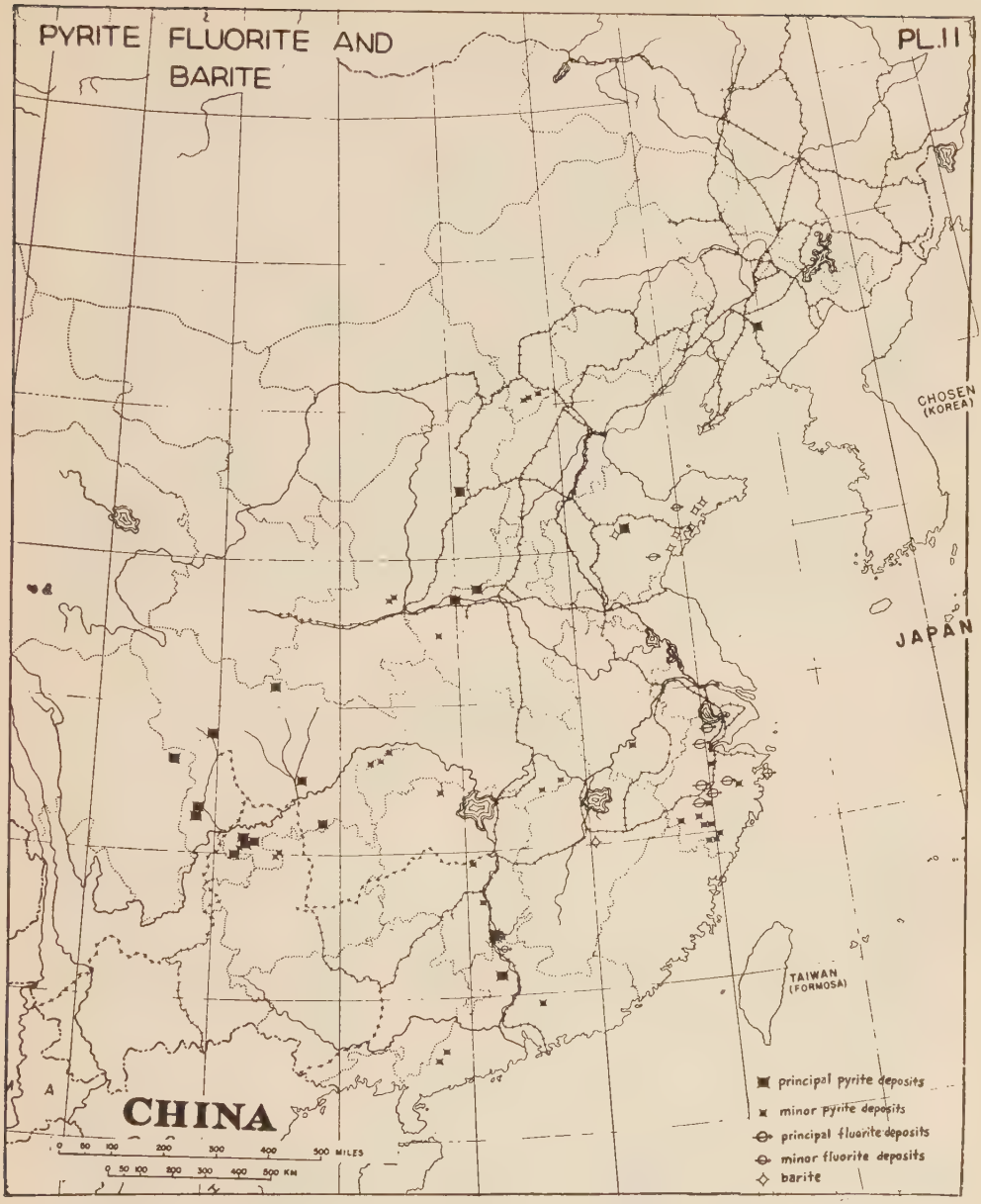
	1935[a]	1936[a]	1937[a]	1938[a]	1939[a]
Szechuan	25,728	28,288	35,968	47,042	50,560
Sikang	12,411	12,004	12,421	18,961	24,435
Kwangsi	7,350	7,377	7,514	7,600	7,700
Kueichow	—	—	—	3,840	1,280
Yunnan	—	—	—	2,000	2,000

[a] Chin, Y. H., Spec. Rept. Geol. Surv. China, no. 6, 1941.

would greatly strengthen China's foreign exchange, and consequently her position in international trade.

Pyrite.

The principal source of sulphur in China (Fig. 11) is the pyrite deposits which are widely distributed throughout the eastern part of the country. There are two types: hydrothermal veins and irregular bodies are the important sources in South China. The lenticular and concretionary deposits in the coal seams of Carboniferous and Jurassic are the predominate type in North China. The vein deposits are found in Hunan, Chekiang, Szechuan, Kwangtung and Sikang. They are frequently associated with copper, arsenic, tin, lead and zinc ores. The pyrite concretions in the coal series usually occurring in certain layers of a few centimeters to over 1 meter in thickness, are found in Honan, Hopeh, Shantung and Szechuan provinces. Ore of this type carries large amounts of impurities and is of inferior grade. However, the abundance of this type of deposit played a large role in China's pyrite production. China produced 4,500 to 5,000 tons annually of pyrite before the war, of which more than 80 per cent was obtained from concretionary ore in North China. Production statistics for recent years are not available.



China's domestic production of sulphur has been insufficient and is supplemented by an annual import of 2,000 to 3,000 tons of sulphur from Japan.

Fluorite.

Except for two small deposits in Shantung and one in Kwangtung, the important fluorite deposits of China (Fig. 11) are found in Chekiang where

TABLE 40.

KNOWN RESERVES OF PYRITE VEINS IN SOUTH CHINA.

(Metric tons.)

Province	Tonnage	Province	Tonnage
Hunan	200,000	Kwangtung	527,000
Anhui	10,000	Szechuan	6,186,000
Chekiang	25,000	Sikang	1,300,000
		Total	8,248,000

at least 16 deposits have been worked in the northern, central and coastal regions. The fluorite forms irregular veins in rhyolite ranging from a few centimeters to more than 6 meters; thicknesses of 2 to 3 meters are common. The known and estimated length ranges from 20 to 3,500 meters, but generally the length is about 100 meters. Some of the veins consist entirely of fluorite masses, others are composed of frameworks of silica filled by fluorite crystals. The fluorite is generally suitable for industrial uses, particularly as a flux. Shipping grade of the best material appears to have averaged 90 to 95 per cent CaF_2 and of lower grade material, over 80 per cent. The reserves of fluorite in Chekiang deposits have been investigated and amount to 400,000 metric tons of fluorite.

TABLE 41.

PYRITE PRODUCTION IN CHINA.

(Metric tons.)

	1932	1933	1934
Hunan	888	751	554
Shansi	650	670	600
Honan	550	550	550
Chahar	20	10	10
Anhui	20	20	20
Szechuan	100	100	100
Shensi	20	20	20
Shantung	1,500	1,500	1,500
Hopeh	60	60	60
Liaoning	1,100	500	1,000
Others	220	200	200
Total	5,018	4,281	4,464

Fluorite mining in China began only in the First World War when the mineral was greatly in demand. The output of fluorite suffered marked decline as a result of the weakened foreign market immediately after the war. In 1928, the 13,000-ton peak was reached, but only 8,000 tons were produced in 1929. Production declined to 3,510 tons in 1932 and increased slightly since then. Of the total output, Chekiang contributed over 90 per cent, only a few tons came from Shantung and Kwangtung. Nearly all the output was exported, principally to Japan.

TABLE 42.

FLUORITE PRODUCTION IN CHINA.

(Metric tons.)

	Chekiang	China
1932	3,500	3,510
1933	4,500	4,800
1934	5,000	5,000

In view of the occurrence of fluorite deposits in Chekiang where the volcanic rocks, in which the fluorite occurs, cover a wide area, new discoveries may be possible in the future. The Chekiang deposits are the principal source of fluorite in the Far East, though in Siberia the mineral is found in comparative abundance and of high quality. Chekiang deposits are able to supply the post-war requirement of the steel industry of China.

Barite.

Barite deposits have been mined in Shantung and Kwangtung but have also been discovered in recent years in Szechuan (Fig. 11). Shantung has been the leading producer in China. Barite occurs as veins in Cretaceous red sandstone in association with vein quartz and in places with galena. The quality of the deposits is said to be high but the extent is not known. The output in part was consumed in pottery and glass industries and in part exported.

TABLE 43.

BARITE PRODUCTION IN CHINA.

(Metric tons.)

1932, 505; 1933, 3,092; 1934, 9,500

Alunite.

Alunite deposits are found on the border of Chekiang and Fukien near the coast and in Lukiang district in Anhui. Alum obtained from alunite is reported to have been produced in Szechuan, but information on the exact location is not available.

In Chekiang and Fukien, the alunite or alumstone is an alteration product of interbedded rhyolite and tuff. Three grades of ore have been recognized:

TABLE 44.

KNOWN RESERVES OF ALUNITE IN CHINA.

(Million metric tons.)

Province	Tonnage of Alumstone	Alunite Content	Tonnage of Alunite
Chekiang	2,042	50%	1,021
Fukien	1,500*	50%	750
Anhui		19–53%	13
Total in China			1,784

* Estimated.

pure alunite beds, alunitized tuff, and alunitized rhyolite. The alunitized tuff and alunitized rhyolite contain 66 and 41 per cent alunite respectively. On the average, the pure alunite beds contain 19 to 26 per cent Al_2O_3, 4 to 6 per cent K_2O and less than 1 per cent Na_2O. It is known that the alumstone zones in Chekiang and Fukien are persistent both laterally and vertically. In Anhui, six rich alunite beds have been worked. The beds are more or less persistent down the dip, but vary greatly in thickness. The average content of alunite is 19 to 53 per cent, equivalent to 17 to 26 per cent Al_2O_3. Rock with 30 per cent alunite can be mined profitably.

All alunite has been mined for extraction of alum which is used chiefly as water purifier and to a limited extent in paper manufacture, fertilizer and medicine. Alunite is considered a potential source of aluminum.

TABLE 45.

ALUM PRODUCTION IN CHINA.

(Metric tons.)

	Chekiang	Fukien	Anhui	Szechuan	Total in China
1932	7,000	1,800	2,200	70	11,070
1933	10,800	2,000	2,000	70	14,870
1934	12,000	1,000	2,480	70	15,550

Bauxite.

Bauxite occurs as sedimentary beds in coal series in Liaoning, Shantung, Kueichow, Yunnan, Hainan Island and Kansu province (Fig. 12). The bauxite beds show either oolitic or amorphous textures and are generally compact and resistant to weathering. They extend for considerable distances.

Except the deposit in Kansu which is not fully investigated, deposits have about 50 per cent Al_2O_3. Although the grade is lower than the bauxite in Malaya, Netherlands Indies and Ponape, the bauxite in Liaoning has been used for aluminum production and Shantung deposits were also once exported to Manchuria and Korea in 1938. The main objection of this material as an important source of aluminum under normal conditions is its high silica content which ranges from 16 to 43 per cent. However, a modified Bayer

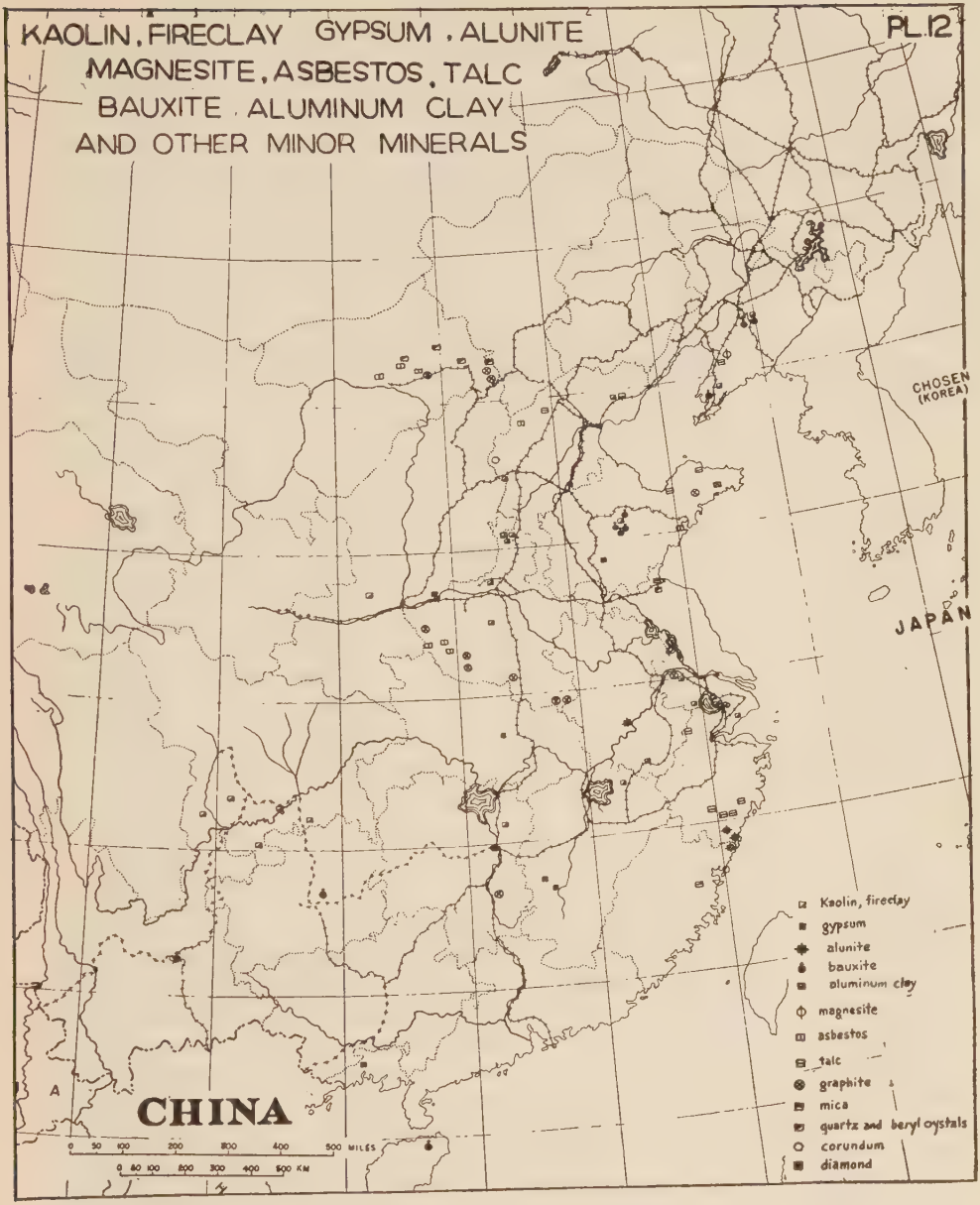
TABLE 46.

RESERVES OF BAUXITE IN CHINA.

(Metric tons.)

Province	Al_2O_3 Content	Tonnage of Bauxite
Liaoning	53%	110
Shantung	59%	271
Kueichow	53–73%	100
Yunnan	50%	50*
Kansu	22–38%	351
Total		882

* Estimated.



process is known to have been developed for manufacturing aluminum from material of this type. The inherent high cost of production could be reduced by further improvement of this process and possibly by the use of a cheaper supply of hydro-electric power in manufacturing. China has rather extensive deposits amounting 882 million tons of bauxite of all grades.

Aluminum Clay.

Aluminum clay deposits with an alumina content of 31 to 70 per cent are found in coal series in Tzuhsien and Kaiping basins in Hopeh province (Fig. 12). The thickness of the bed is generally somewhat over 1 meter and is locally as much as 4 meters. The reserves of the clay in Kaiping basins has been estimated at 5 million tons and that in Tzuhsien at 7 million tons. Whether this material will be used as a source of aluminum depends on the same factors as those mentioned in connection with the use of siliceous bauxite, but it will have value in the manufacture of refractories.

Kaolin and Fireclay.

Kaolin and fireclay deposits are found at scattered localities in South Manchuria, North China, and the Yangtze Valley (Fig. 12). Almost all the

TABLE 47.

Estimated Production of Kaolin in China.

(Metric tons.)

	1932	1933	1934
Kiangsi	152,000	133,000	140,000
Hopeh	192,000	212,000	212,000
Shantung	75,000	80,000	80,000
Anhui	2,000	1,650	3,000
Kiangsu	60,000	60,000	60,000
Fukien	50,000	50,000	50,000
Kwangtung	60,000	60,000	60,000
Shansi	50,000	50,000	50,000
Szechuan	50,000	50,000	50,000
Honan, Shensi, Hunan	100,000	100,000	100,000
Liaoning	51,800	112,070	120,000
Kirin	20,000	35,000	100,000
Total	862,800	943,720	1,025,000

deposits occur with coal beds; a few are products of weathering of old rocks. The best known kaolin deposit used for making porcelain is found in Kingtechen in Kiangsi province where an industry was established as far back as 210 B.C., but the deposit has never been scientifically investigated and both its extent and the production in recent years are unknown. Kimen deposits in Anhui are known to be large and of high quality and have been used by many porcelain factories in Anhui as well as other provinces. All of the deposits in South Manchuria, North China as well as the deposits in Szechuan are found in stratified beds. Some are high in alumina and suitable for manufacture of refractory fire brick, others are high in feldspar and are best for the production of china. The porcelain industry in North China is not on as large a scale as that in South China, but manufacture of fire brick is developing very rapidly under the impetus of industrial uses.

Statistics on production of kaolin are rather incomplete. The production of fireclay, though considerable, is not a matter of record.

It is believed that the kaolin and fireclay deposits are quite extensive and

that the high quality kaolin to be used for producing the best porcelain is in considerable supply. Large quantities of sandy clays are a potential raw material in the cement industry.

Gypsum.

Gypsium is so far produced at present only in Shantung, Shansi, Hupeh, Hunan and Kiangsi (Fig. 12). Among these provinces Hupeh, Hunan and Shansi are the large producers. Gypsum occurs exclusively as thin beds in the red beds of Cretaceous or Tertiary age, and is associated with salt which is produced as a by-product.

China produced about 67,000 tons of gypsum in 1934, of which Hupeh contributed more than 85 per cent. Pre-war gypsum consumption in China probably did not exceed 70,000 tons, nearly half of which was used in cement manufacture. Production can be increased, but the inevitable high cost of mining this type of deposit makes it unlikely that local sources can furnish enough gypsum to meet the ever-increasing industrial demand.

TABLE 48.

GYPSUM PRODUCTION IN CHINA.
(Metric tons.)

	1932	1933	1934
Hupeh	57,996	57,600	58,020
Hunan	3,512	4,300	7,100
Shansi	2,900	2,000	2,500
Kwangtung	100	120	100
Total	64,508	64,020	67,720

Magnesite.

Magnesite deposits of workable grade have been found only in Liaoning province (Fig. 12). The deposits are all situated near the main line of South Manchuria Railway in an area of about 60 square kilometers. They are replacement deposits of coarsely crystalline magnesite in masses interbedded and interfingering with dolomite. The material is of good grade, ranging from 44 to 48 per cent of MgO with a low content of impurities. Individual deposits are large and are suitable for open-cut mining.

TABLE 49.

MAGNESITE PRODUCTION IN CHINA.*
(Metric tons.)

Year	Tonnage	Year	Tonnage
1931	36,034	1935	134,220
1932	55,386	1936	191,568
1933	72,276	1937	331,000
1934	75,660	1938	401,000

* ECON. GEOLOGY. vol. 31, 1927, p. 768; Mineral Yearbook, 1940, U. S. Bureau of Mines, 1942.

The magnesite production in China was small until 1930. In 1938, 401,000 tons of magnesite were produced, 60 per cent of the output being exported to Europe and the United States and most of the remainder to Japan.

The magnesite deposits of China are known as the largest in the world. The total reserves in Liaoning amount to 200 to 5,000 million tons. Future expansion of the production of magnesium metal in the Far East is very desirable. Many countries are engaged in the export of raw materials in small quantity, but few export magnesium compounds and the metal. Magnesium extraction requires more electric power than aluminum extraction from bauxite. In 1941 the world leading producers of magnesium metal were Germany, the United States and the United Kingdom with a total of 61,700 metric tons out of 77,600 tons, the world's output.

Asbestos.

Asbestos deposits in China are not exceptionally promising. Asbestos has been produced in Suiyuan, Hopeh and Honan provinces. The Leiyuan chrysotile deposit in Hopeh is the best known deposit (Fig. 12). It produces fiber 1.5 to 2 centimeters long. Several deposits have been worked in Suiyuan, the longest fiber produced being 1 to 3.5 cm. in length but this grade is limited in quantity. Run-of-mine fiber is .3 to 1.5 cm. long. Honan deposits are even poorer in quality, though the deposits are apparently more extensive. Asbestos has also been produced in Liaoning but the location is not known.

TABLE 50.

ASBESTOS PRODUCTION IN CHINA.
(Metric tons.)

	1932	1933	1934
Hopeh	180	100	150
Suiyuan	50	30	30
Liaoning	120	106	110
Total	350	236	290

The asbestos industry was centered before the war at Tientsin in Hopeh province, where asbestos products were manufactured. Of the provinces not yet exploited, Kwangtung and Sikang seem to possess promising deposits.

Talc.

China possesses vast reserves of high-grade talc in Liaoning, Chekiang and Fukien (Fig. 12). The Liaoning deposits are closely associated with magnesite deposits and have quality suitable for use in the paper and cosmetic industries. Although classified in the trade as talc, the Chekiang and Fukien deposits are really pyrophyllite occurring as veins or as an alteration product of rhyolite and tuff. The best quality pyrophyllite is used in carving objets d'art while that of inferior quality is mined for similar uses as that of Liaoning. The production of talc in these two provinces has been small.

Detailed figures for the production of different deposits in recent years are not available. Data for 1937 to 1940 indicate that China far outstripped all countries except the United States. Most of the output was exported to Japan and the United States.

TABLE 51.

EXPORT OF TALC FROM CHINA.[1]

(Metric tons.)

1937	111,140
1938	81,215
1939	93,772
1940	72,495[2]

[1] Mineral Yearbook, 1941, U. S. Bureau of Mines, 1943, p. 1398.
[2] January to September inclusive.

With proper exploitation of deposits in Chekiang and Fukien, China will not only meet the increased demand of her domestic industries, but will have a great surplus for export.

Minor Minerals.

Although graphite deposits have been found in Suiyuan, Shantung, Honan, Kiangsu and Hunan, none of them appear to be large. China contributed only a negligible quantity of crude graphite to the world output.

One mica deposit is definitely known in Kiangsu, but it has never been mined on a commercial scale. A mica deposit of superior quality is reported to have been found in West Yunnan, but the location and extent of the deposit is not known.

Quartz and beryl crystal have been produced in Suiyuan and Kiangsu. One corundum deposit and one diamond deposit have been found in Hopeh and Shantung respectively.

Phosphate.

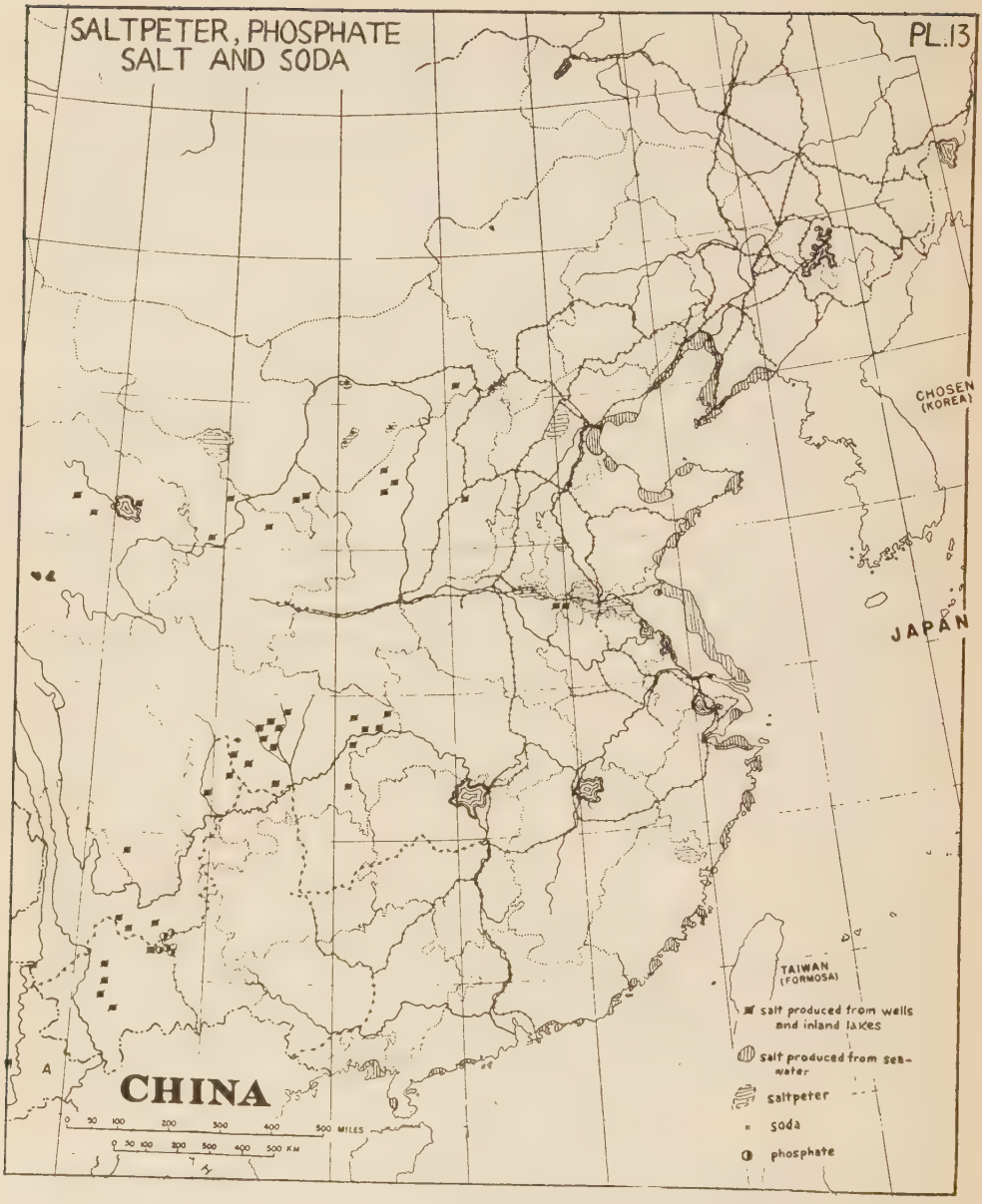
The sources of phosphate in China are the apatite deposit in Kiangsu, guano on the islands off the coast of Kwangtung and rock phosphate in Yunnan (Fig. 13). The apatite deposit mined is in Tunghai district, occurring associated with manganese ore as a replacement deposit in schist. The average grade of shipping ore has 33 per cent P_2O_5. Guano occurs on Paracel Islands, southeast of Hainan Island, and in Pratas Island, southwest

TABLE 52.

PHOSPHATE RESERVES IN CHINA.

(Metric tons.)

Province	Tonnage of Ore	P_2O_5 Content	Tonnage of P_2O_5
Kiangsi Apatite	2,280,000	30–40%	684,000
Yunnan Phosphate Rocks	42,000,000	23–38%	12,000,000
Kwangtung Guano	175,000	10–15%	21,000
	1,000,000	30%	300,000
Total			13,005,000



of Hongkong. The deposits of this type carry between 10 and 15 per cent P_2O_5. Yunnan phosphate rock was discovered only in recent years. It occurs as sedimentary beds in quartzites and limestones of pre-Cambrian and Cambrian age. The ore is of high grade, ranging from 23 to 38 per cent P_2O_5. The total reserves of phosphate rock deposits are about 13 million tons of P_2O_5.

Apatite production of Kiangsu, estimated at about 8,000 tons a year between 1935 and 1939, was exported entirely to Japan. Production of guano was formerly at the rate of about 5,000 tons a year. Phosphate rocks in Yunnan were mined only by local farmers; output has been negligible.

Saltpeter.

Saltpeter is, at present, produced only in Hopeh, Honan, and Kiangsu (Fig. 13). The mineral is obtained by leaching the thick crust collected on top of the soil and evaporating the solution. The production of saltpeter in Hopeh was estimated about 1,200 tons a year; in Honan, 800 tons a year; in Kiangsu, 30,000 tons in 1932.

There are many regions of potential supply, of which South Suiyuan, eastern Kansu, western Shantung and north Fukien are reported as of importance.

Soda.

Natural soda is produced in Ordos Plateau of Suiyuan, in the northern Shansi and in eastern Honan (Fig. 13). It occurs in bedded form and is accumulated in winter time. The material is prepared by dissolving first in water with subsequent boiling until crystallization ensues. This is known as crude soda and is exported to Chahar or Hopeh for refining. The annual production of crude soda in Suiyuan has been about 2,970 tons, and that in Honan, ranged from 1,200 to 2,000 tons. Refined soda produced in Hopeh in 1934 amounted to more than 37,000 tons.

Salt.

Crude Salt Production and Distribution.—The salt industry of China is under government control. As China has more than 400 million consumers, salt plays an important part in the economic and political life of China.

The sources of supply of salt are widespread and diverse (Fig. 13). A large part of the salt consumed is obtained from sea water. Salt works are found along the coast from Korea south to Indo-China. In the inland areas, salt is produced from brine wells, salt lakes and "salt earth." In the southwestern region, where red beds are present, wells are drilled and mines are periodically flooded. Salt is obtained from the resulting brine and gypsum is obtained as a by-product. In Yunnan and Szechuan, a large amount of salt is produced from natural salt brine in wells. In the northwestern region salt lakes provide a supply of salt for local consumption. A small supply of poor-quality salt is found along Huangho in Honan, where what is called "salt earth" occurs. The top layer of the soil is impregnated with various salt and yields a product containing 62 to 86 per cent sodium chloride. The accompanying map gives the general distribution according to method of production.

Sea Salt from Coastal Region.—As already noted, all the coastal provinces of China produce sea salt, Liaoning, Kiangsu, Shantung and Hopeh being the large producers. For the production of sea salt, a flat, low-lying shore is selected and a simple lay-out is built on the sandy beach. A main sea-dike

cuts off the evaporation pans from the sea and there are feeder canals to admit sea water. Solar evaporation is mainly used, but boiling is resorted to in the final stage of production. Production is under private management, the government function being purely one of supervisory control. More than 75 per cent of China's total salt production is obtained from sea water.

TABLE 53.

SALT PRODUCTION IN CHINA.

(Piculs, 16.5 piculs = 1 metric ton.)

Province	1932	1933	1934	1935	1936	1937
Liaoning	10,000,000	12,000,000	6,880,500	14,883,000	12,969,000	12,606,000
Hopeh	4,439,000	4,307,000	4,400,000	—	—	—
Shantung	7,569,000	8,340,000	8,800,000	—	—	—
Kiangsu	8,362,000	8,345,000	8,460,000	—	—	—
Chekiang	4,222,000	4,235,000	4,200,000	—	—	—
Fukien	2,076,000	1,471,000	2,000,000	—	—	—
Kwangtung	3,000,000	3,000,000	3,000,000	—	—	—
Suiyuan	—	—	13,800	—	—	—
Shansi	194,000	184,000	182,000	—	—	—
Honan	1,500,000	1,500,000	—	—	—	—
Hunan	17,820	16,830	16,830	—	—	—
Hupeh	148,000	150,000	150,000	—	—	—
Sikang	30,000	45,000	50,000	48,000	47,000	50,000
Yunnan	488,000	479,000	480,000	778,000	935,000	956,000
Szechuan	5,890,000	4,750,000	5,200,000	7,340,000	7,390,000	7,091,000
Kansu and Shensi	30,000	50,000	50,000	—	—	—
Ningsia	92,000	95,000	90,000	—	—	—
Tsinghai	10,000	8,000	15,000	—	—	—
Sinkiang	24,000	37,000	—	—	—	—
Total	52,190,000	52,992,000	53,686,000			

Well Salt in Inland Areas.—Production methods in the inland areas differ markedly from those in the coastal region. Salt brine wells in Szechuan and Yunnan have been developed into a large industry. In Szechuan well borings are sunk as deep as 1,000 meters by crude machinery. All salt is obtained by evaporation by means of solid fuel or gas. Saline rock mining is prosperous in Hupeh, Hunan, Sikang and western Yunnan. Wells are drilled in the red beds in which thin layers of rock salt and salt disseminations are found. The salt is leached out by flooding and the resulting brine boiled down. Lake salt is mainly produced in Tsinghai, Kansu, Sinkiang, Suiyuan and Shansi. Salt mining in lakes is not pursued by professional miners and production is confined to winter time when the lake water subsides. The salt is purified by recrystallization. Honan is the only province in which "salt earth" is produced. The work is intermittent and the quality of salt is poor.

Salt Refining.—Salt refining is a comparatively recent industry. Most of the salt refining takes place near the coast in Hopeh, Shantung, Kiangsu, and Chekiang and is entirely restricted to sea salt. The total quantity of refined salt amounts to only 2 per cent of the total salt production, or about 1,130,000 piculs a year.

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